ELECTRICAL ENGINEERING

SEPTEMBER 1948

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1948

AIEE MIDDLE EASTERN DISTRICT MEETING, WASHINGTON, D.C., OCTOBER 5-7, 1948

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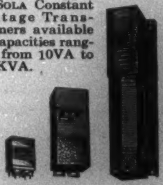

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ELECTRICAL ENGINEERING

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SEPTEMBER
1948

The Cover: Steam turbine rotors being assembled in the Allis Chalmers Company plant, Milwaukee, Wis. This is one of the many interesting manufacturing processes included in the field inspection trips scheduled for the Midwest general meeting at Milwaukee, Wis., October 18–22, 1948.

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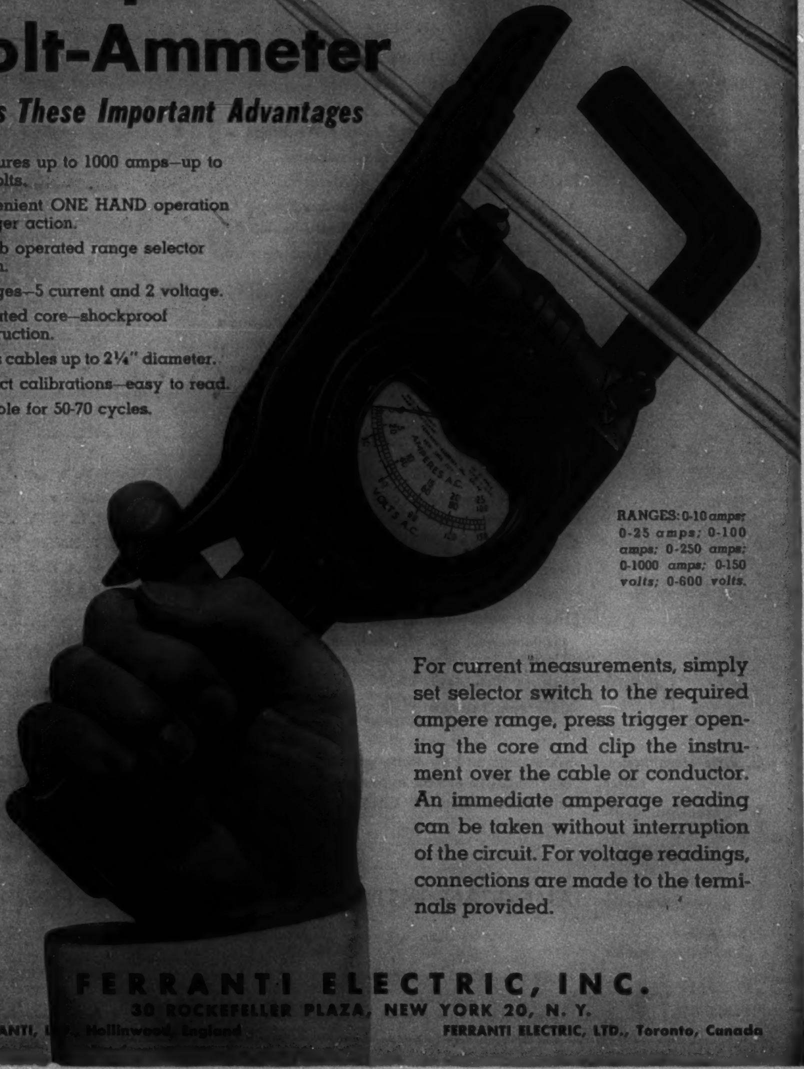

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HIGHLIGHTS........

Frequency Change. Shifting the frequency of a large power system from 50 cycles to 60 cycles means far more than simply speeding up the generators, involving as it does, everything from possible "creep" in turbine blades because of greater centrifugal forces to the hundreds of thousands of electric clocks in the homes of 700,000 customers. However, with proper planning, two years of work, and $35,000,000, the Herculean task can be accomplished (*pages 866–81*).

European Engineering Practices. Power generation, transmission, and protection as engineered in Europe are described and compared with American practices. The authors speak from personal experience with a European electric equipment manufacturing company (*pages 835–42*).

New Method for Determining Synchronous Reactance. Of particular interest to students and instructors of electric machinery, a novel method of measuring the direct and quadrature synchronous reactances of a salient pole synchronous machine is presented. This modified slip test permits a detailed investigation of machine constants under more reliable conditions than provided by previous methods (*pages 890–2*).

Measurements. Quantities to be measured and devices for measuring them may be analyzed and tabulated in such a way as to aid in the selection of suitable devices (*pages 849–59*).

Health Physics Fights Radiation Hazards. The tenth article of the series developed by the AIEE nucleonics committee discusses the methods employed by an atomic power laboratory to prevent injury to personnel and the possible effects of overexposure to ionizing radiations (*pages 884–90*). A consolidated pamphlet of reprints including the entire series will be available to interested readers upon completion of the series.

Aircraft Safety. By summarizing the conflicting points of view expressed at the 1947 winter general meeting's conference on aircraft safety, this article serves both as a résumé for those not present at the conference and as a quick reference for those who were (*pages 901–4*).

Network Theory. The growth of network theory falls into three phases; a decade of infancy, a decade of adolescence, and a decade of maturity—which is reviewed in this article (*pages 895–9*).

Starting Devices. A review of the operation of five starting devices—one of them a new phase-angle eddy-current action relay—is given. Also a description is given of the characteristics of a single-phase induction motor of the split-phase or capacitor-start type as influenced by each device (*pages 862–4*).

President's Message. Outlining some of the problems that need consideration at the beginning of the Institute year, President E. S. Lee presents his second message to the membership in this issue (*page 909*).

Middle Eastern District Meeting. The program of the Middle Eastern District Meeting which is to be held in Washington, D. C., October 5–7, 1948, promises to be an interesting one. The program including inspection trips and other activities appears in this issue (*pages 910*).

Midwest General Meeting. Plans for the various activities scheduled for the Midwest general meeting to be held in Milwaukee, Wis., October 18–22, 1948, are outlined in this issue. The technical program, inspection trips, entertainment, sports, and women's program are covered. The full technical program is scheduled for publication in the October issue (*page 912*).

Rectangular Hysteresis Loops. Certain magnetic materials may be treated in such a way as to have rectangular hysteresis loops. The first practical applications to electrical apparatus of this unusual property have begun, and many more are expected, particularly in saturable devices and equipment operated at high flux densities, as the full significance becomes appreciated by designers (*pages 843–5*).

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Digests and Abstracts. As usual, a number of one-page digests appear in this issue. With the exception of two from the Northeastern District meeting (*pages 848 and 893*), all are digests of papers presented at the summer general meeting (*pages 846, 847, 860, 861, 865, 882, 883, 894, 900, and 906*). One-page digests were not received for a few of the summer meeting papers. These are being presented in abstract form in this issue (*pages 907–8*).

Section Operation and Management. The problems of section operation and management were discussed at some length during the summer general meeting in Mexico. Such topics as the model Section, establishment of an international Section at Niagara Falls, bylaw changes, and women's auxiliaries, were discussed (*page 915*).

Sightseeing trips to points of interest such as these are scheduled during the Middle Eastern District Meeting, in Washington, D. C., October 5-7, 1948. Shown here is the Washington monument with a portion of the Pan American Union gardens in the foreground

Correction. As a result of printer's errors, Doctor Harvey N. Davis was referred to incorrectly as Harry N. Davis in two places in the August issue of *ELECTRICAL ENGINEERING;* in the byline to his article, "The Engineer's Part" (pages 727-33), and in the table of contents reference to the same article.

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ALPETH

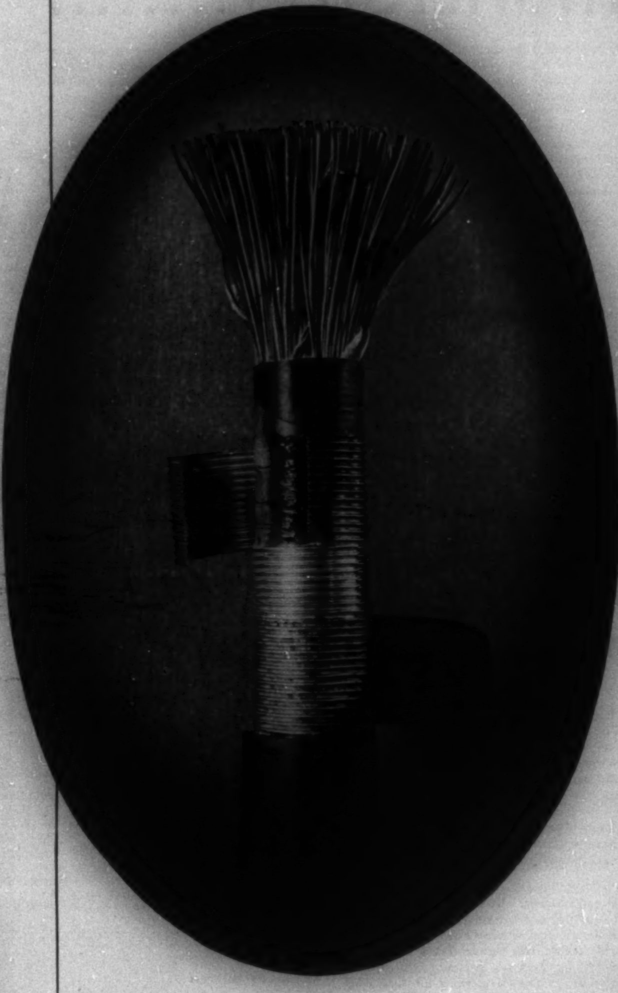
NEW WORD ON TELEPHONE CABLES

Lead makes an excellent sheath for telephone cables — sixty years and thousands of miles in service have well proven that. But lead is useful in other ways—storage batteries and paint, to name only two. So the telephone industry shares the limited available supply with other claimants.

Before the war when there was no lead shortage, Bell Laboratories engineers sought to develop better and cheaper cable sheaths. An ideal sheath is strong, flexible, moisture-proof, durable and must meet specific electrical requirements. No single material had all those virtues, so thoughts turned to a composite sheath, each element of which should make a specific contribution to the whole.

Various materials and combinations were studied. Desirable combinations that satisfactorily met the laboratory tests were made up in experimental lengths, and spent the war years hung on pole lines and buried in the ground. After the war, with an unparalleled demand for cable and with lead in short supply, selection was made of a strong composite sheath of ALuminum and PolyETHylene. Now Western Electric is meeting a part of the Bell System's needs with "*ALPETH*" sheathed cable.

Meeting emergencies—whether they be storm, flood or shortage of materials — is a Bell System job in which the Laboratories are proud to take part.



BELL TELEPHONE LABORATORIES

• EXPLORING AND INVENTING, DEVISING AND PERFECTING FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE.

European Engineering Practices

M. J. DeLERNO
ASSOCIATE AIEE

F. V. G. BIRD
MEMBER AIEE

Oerlikon

The interest of both European and American engineers in the engineering practices of the other group has been intensified by the part American engineers will play in the reconstruction of Europe. Both authors have studied the engineering techniques in the various European countries and in the United States and are well qualified to summarize the differences which exist.

GENERAL European electrical engineering practice differs in several respects from American because of the individual approach to electrical problems taken by the founders of the science of electrical engineering. The choice of 50 cycles per second as the standard industrial frequency in most of Europe and $16\frac{2}{3}$ cycles per second (one-third of 50 cycles) as the standard low frequency is only one example. It is impossible to say whether the choices made are considered unfortunate ones which must be endured or whether they are favored actually at the present time. (In the United States, 50 cycles gave way to 60 cycles and two phase to three phase although there are some installations still remaining in the old categories.) At the present time serious consideration is being given in Europe to the solid grounding of the neutral of transmission systems above 220 kv, whereas up to the present time all transmission has been carried out ungrounded. These two facts indicate possible changes had it been felt that the principles inaugurated by the founders of electrical engineering had been sufficiently disadvantageous.

In addition to different frequency standards, the lowest distribution voltage is different. The value is 220 volts, single phase, and 380 volts, three phase. In some countries the distribution system neutral is grounded while in others it is left ungrounded, provision being made to prevent dangerously high line-to-ground voltages through spark gaps. The neutral point of the transmission and generating systems remains ungrounded in all major European countries but Great Britain. This ungrounded neutral gives rise to certain problems not encountered on grounded systems.

Power-system interconnection between different countries has not existed to an appreciable extent up to the present

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M. J. DeLerno and **F. V. G. Bird** are electrical engineers with Ateliers de Construction Oerlikon, Zurich, Switzerland. The sections on electric railroad engineering and relay engineering were prepared by Bird, the others by DeLerno. DeLerno, an American engineer interested in European practices, has spent a year studying the domestic and export practices of this company. Bird, an English engineer, has been employed in an engineering capacity on the railroads of England and France, has been associated with the British electric transmission networks, and has worked for a manufacturer of electric equipment in Great Britain.

The headpiece shows the machine room of the La Dixence power station, Wallis, Switzerland. Total generating capacity is 194,500 kilovolt-amperes; speed, 500 rpm; height of head, 5,750 feet. This is the largest high-head development in Europe.

time. Total system capacity in each country nowhere approaches that of the United States so that problems introduced by this large capacity such as circuit breaker interrupting capacity and system stability are not as great. Lightning phenomena recurs less frequently in Europe, although it presents greater problems when it occurs because of the ungrounded systems.

Mass production techniques do not exist to an extent comparable to those in the United States. Because of this, more custom-made equipment is manufactured involving special engineering principles. Products not manufactured in the United States because of their applications to relatively few uses still are produced in Europe. The part played by electronics in industrial processes has not been developed to such a great extent in Europe so that special mechanical and electric devices have been produced to perform these functions. These devices usually show good engineering thought and development but in many cases are more costly than a similar device produced electronically. Again it is impossible to trace the reason for this trend, although it is believed to be more a result of an insufficient number of electronic parts manufacturers than of a prejudice on the part of engineers to use anything which operates electronically.

The most annoying problem with which the European electrical engineer engaged in the design of equipment for export must contend is that of standards. Those engineers in the United States who feel that fire codes, state codes, Underwriters specifications, and American Standards Association standards are an unnecessary duplication of codes cannot appreciate the problems of design connected with a series of standards different in requirements for the same components or for similar performance. Each country has its own code in addition to the International Electrotechnical Commission Code to which the manufacturer usually must conform. This necessitates rating a single piece of equipment for different values, depending upon the country for which it is destined. It is difficult to say which standard is most severe because each standard has its own particular section on which great stress is placed.

MOTOR AND GENERATOR ENGINEERING

In Europe, the ratio of hydraulically-produced power to steam-produced power is considerably greater than in the United States. Although the locations of the chief sources of water power are in Norway, Sweden, and Switzerland; France, too, has sizeable water power resources. The majority of these sources of energy are available as high-head low-volume sources, so that it is normal to use a Pelton impulse turbine or a Francis reaction turbine as a prime mover. Because these turbines are designed for relatively high speeds, it is necessary that the alternators be designed for high-speed operation as well. Instead of attaching the rotor poles to cast spiders, as is the usual construction for low-speed units, these high-speed rotors are usually of built-up construction, thus ensuring greater strength to withstand the large centrifugal forces present. These high-speed units are constructed for both vertical and horizontal installations, the Pelton wheel being quite suitable to horizontal mounting. The headpiece shows the horizontal Pelton-wheel installation in the LaDixence power station in Switzerland, the largest high-head development in Europe. There are, of course, several low-head high-volume developments throughout Europe and, in general, these alternators are designed along the same lines as in the United States.

In the steam turbogenerator field, the use of hydrogen as a cooling medium for the generator has not been employed in other than experimental units. Only a few such units exist and progress in this field is slow. Closed-cycle and open-cycle air cooling are the normal methods of cooling in use. As is the case with the high-speed hydraulic rotors, the present tendency is to construct turborotors of built-up construction, eliminating the through shaft, and instead, bolting the shaft ends to a built-up body. Greater stresses can be allowed without the danger of failure which is present in cast rotors.

Field excitation and supression systems follow the same pattern as in the United States. Exciters are built with special magnetization characteristics to permit smooth changes in voltage and these exciters usually are mounted on the prime-mover shaft. Stator or rotor skewing to minimize magnetic-reluctance variation is the accepted practice. Alternators are designed to produce various rated voltage levels, the highest voltage levels being about 33 kv in Great Britain and 25 kv in Germany.

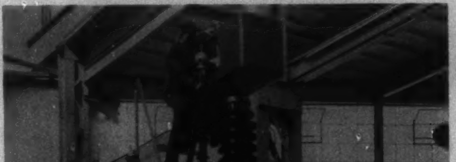


Figure 1. Tap-changing transformer of 30,000-kva capacity

There are 32 available voltage taps ranging from 116 to 160 kv

Industrial-type motors are of diversified types. Instead of calling upon several standardized types to fill all applications the tendency is to construct a specialized unit for a particular or unusual application. The brush-shifting shunt commutator motor or Schrage motor is very popular and is built in sizes up to and greater than 200 horse power. This motor satisfies those variable speed applications where a thyratron-controlled d-c motor would be used in the United States. Remote control of the brush-shifting gear is accomplished with a servomotor and its associated control. The synchronous-induction motor also finds several uses where high starting torque and low inrush current are required but where synchronous motor operation under normal conditions is desired. Air-compressor and cement-kiln drives are two applications using this type of motor. Double squirrel-cage motors are used also where high starting torque is required. Wound-rotor induction motors used for high starting torque duty with constant speed operation usually are fitted with combined rotor short-circuiting device and brush lifting mechanism. The short-circuiting device rotates with the rotor and can be operated externally to short-circuit effectively the rotor internally, thus making it possible to lift the brushes under rotor-short-circuited or normal operating conditions. Induction motors requiring low starting current usually have both ends of each phase brought out so that the motor can be started in Y and switched to delta after reaching near-operating speed. This method is preferred to compensator or primary resistance start where current inrush must be limited.

TRANSFORMER ENGINEERING

The principal difference between European and American practice occurs in the application of transformers to electric systems. The percentage of single-phase transformers produced is relatively small—its use in 3-phase circuits is restricted to the very largest sizes where 3-phase transformers would be too large. Core-type 3-phase transformers are used almost exclusively in the ungrounded 3-phase networks of continental Europe. The Y-to-Y connection with 4-wire secondary is usable with 3-phase core-type transformers if only a small (several per cent) line-to-neutral load unbalance exists because of the almost complete elimination of third harmonics in the line-to-neutral voltage as well as the slight shift of the neutral point. The lower phase voltage and higher phase current of this connection provide conditions favorable to sound construction and more economical manufacture. Use is made also of the Y-to-zigzag connection for cases involving serious line-to-neutral unbalance. While this connection involves more secondary copper than a secondary connected in Y, the primary requires fewer turns and hence less insulation than a delta-connected primary (the other feasible connection for a load of this type without primary neutral being Δ-to-Y). In cases involving high primary voltages and low power outputs, the saving in primary insulation more than offsets the added copper cost of the secondary. Tap-changing transformers find almost as many applications as do fixed-ratio transformers. The use of synchronous condensers for voltage regulation assumes secondary importance to that of tap-changing transformers. In the power-transmission sizes, these transformers generally are constructed with provisions for tap changing under load. Figure 1 shows a power transformer of this type. The short-circuiting contactors are located externally to the transformer, thus preventing the transformer insulating oil from being contaminated by carbonized oil produced by the arcing action of the contacts. The principal tap-changing contacts, which are not subject to arcing, are located usually within the transformer tank. The complete mechanism is motor-driven through a rotatable shaft, this shaft being constructed of a high-voltage insulator if the transformers have ungrounded neutrals. The smaller distribution transformers usually must be removed from the line before tap changing can be accomplished. Regulation of from plus or minus 10 to 20 per cent can be obtained with these transformers. Another use for these units is to control the flow of reactive power between interconnected systems while holding the voltage at a definite value.

Noninflammable oils are used rarely in transformers of European manufacture. Perhaps this can be explained best in that the use of the unit substation at customer's site is unusual. Transformers are installed in substations or outdoors where the danger of extreme damage from fire or explosion is relatively small. The savings in insurance are not sufficiently great in these cases to justify the added expense of this type of oil. The importance of improved heat conductivity is minimized because the transformer size is determined by the per cent losses and not by temperature rise.

Impulse testing of transformers only is beginning to be used as a method of detecting imperfections in transformers. None of the various European engineering standards require impulse testing as a standard production test for transformers. In fact, the number of impulse generators available in Europe to test transformers is quite small. Some manufacturers, however, give an impulse test to each transformer and others only type test with impulse voltage. Some engineers are opposed to impulse testing on the theory that it weakens the insulation against subsequent impulses when in service.

The various European standards for transformers are about as divergent as for any other electric apparatus. Permissible temperature rises for transformer windings vary from 50 to 65 degrees centigrade for dry-type transformers and from 55 to 65 degrees centigrade for oil-filled types. Temperature rises of the oil vary from 45 to 55 degrees centigrade. All of these ratings, however, are less conservative than present-day American (ASA) ratings. Insulation is of the same type as that used in transformers of American manufacture. The high-potential test voltage to which transformers must be subjected is somewhat greater than American standards for low-voltage windings, depending upon the standard in question, but approximates the same value for high-voltage windings.

In other respects, European transformers are similar to those of American design. Individual manufacturers use special techniques and designs for cores, placement of coils, and distribution of electric-field stress between windings and to ground. Cooling follows general practice but forced oil cooling through an external water-cooled heat exchanger is fairly common.

SWITCHGEAR ENGINEERING

For the successful designing of switchgear apparatus adequate testing facilities are an absolute necessity. In Europe there are several high-power testing laboratories available to test circuit breakers of high interrupting capacity. As in the United States, however, the capacities of systems have grown to such an extent that the capacities of the laboratories are inadequate to make full-power tests on circuit breakers for these installations. In addition to field tests on switchgear, which is not easily arranged in Europe, a concentrated effort is being made to develop simulated tests which will correspond to actual load conditions but which will be within the power range of the testing laboratories. The co-ordination of this work is being discussed on an international scale by CIGRE (International Conference on Large High-Voltage Electric Systems) and it is hoped that an international set of standards can be evolved enabling both manufacturer and purchaser to know exactly what the equipment will do, based upon the simulated tests.

It is interesting to compare the thoughts of European engineers with American engineers on the subject of circuit breaker testing. Some of the points of difference are

1. In the United States, the tendency towards restriking of the arc is expressed in terms of the transient rate of rise of gap voltage at the instant of interruption, while in Europe this tendency is expressed in terms of the frequency of oscillation of the gap voltage at the instant of interruption.

2. In single-pole testing of 3-phase circuit breakers, it is customary in the United States to apply only 57.7 per cent of rated line voltage to one pole, whereas for the ungrounded systems of continental Europe, 86.6 per cent of rated line voltage is applied to one pole when conducting similar tests. On ungrounded systems and in certain cases on grounded systems when interrupting a 3-phase short circuit, the gap voltage of the first pole to clear the fault reaches 86.6 per cent of line voltage.

3. Circuit breaker ratings usually are expressed in total interrupting capacity (unsymmetrical current) in the United States, while they are expressed in symmetrical interrupting capacity (d-c component of the current is removed) in some countries in Europe.

The conversion of ratings from European standards to American standards is a difficult task and at best, can, be only an approximation of the true performance. But such a conversion is necessary not only from an engineering comparison viewpoint but from a sales viewpoint as well, especially for those manufacturers engaged in export activity who might be called upon to supply ratings for either sets of standards.

A study of the switchgear apparatus itself discloses independent trends on both continents. The air-blast circuit breaker has been in use in Europe for many years while it has been introduced fairly recently into the United States. Axial and cross-blast types are manufactured on each continent, but there is a preponderance of the axial-blast type in Europe and a preponderance of the cross-blast type in the United States. In the highest voltage ranges, circuit breakers are constructed on the minimum-oil or oil-poor principle rather than on the single-pole oil circuit breaker principle. Oil circuit breakers find their greatest use at voltages below 50 kv where the volume of oil required for the circuit breakers is not excessive. Water circuit breakers in which the interruption occurs with the aid of steam vapor produced by the arc have been developed for voltages up to about 60 kv and were used to a considerable extent in Germany prior to World War II. This circuit breaker never received equal popularity elsewhere in Europe and probably never will be accepted for normal service.

Circuit breaker development proceeds at a steady pace. Various schemes have been tried to increase the interrupting capacities of all circuit breakers, including multiple breaks, greater pressures, and new materials. Means for preventing restriking on magnetizing-current loads with the air-blast circuit breaker using damping resistors and for equalizing voltage distribution between breaks in series with capacitors are being investigated. Automatic reclosing studies on power systems are being undertaken constantly to improve system operation wherever possible. Of course single-pole reclosing of circuit breakers is of no use on an ungrounded system so is not under consideration.

Power drives for circuit breakers are either motor-, magnetically-, or spring-operated. There is no preponderance of magnetically-operated switchgear, and spring-operated driving mechanisms are quite popular, even in the largest sizes. Because of the large closing forces required on the largest circuit breakers, these spring-operated mechanisms are equipped with strong springs which make the drives quite large and intricate. Special design features must be incorporated to ensure satisfactory operating life because of the large impact forces inherent in such a system.

TRANSMISSION ENGINEERING

The three fundamental considerations which have been under investigation by transmission engineers in Europe are

1. Higher a-c transmission voltages.
2. System stability with long-length lines.
3. D-c transmission.

While the highest a-c transmission voltage in commercial use up to the present time throughout Europe is 220 kv, the subject of raising this upper limit has been under consideration for some time. Several power lines which were constructed in Germany prior to World War II were designed to operate at 380 kv but never actually were operated at more than 220 kv. A major consideration at these higher voltages is corona loss on the line. Hollow conductors of sizeable diameter must be employed because of the electric-field distribution pattern. One method developed in Germany, known as the "Bundel-leiter" principle, for minimizing conductor diameter, thus permitting the use of solid conductors, involved the use of multiple conductors for each phase in a specially oriented arrangement. One form studied for use at 400 kv consisted of four conductors per phase, each of 25-millimeter diameter, located at the corners of a square with sides of 400 millimeters. These four conductors were maintained in square formation by spacing frames located between 30 and 35 meters apart. Table I shows the comparison of corona losses between this line and a 50-millimeter hollow conductor line under various weather conditions.

Table I.* **Corona-Loss Measurements at 400 Kv on Transmission Lines**

Weather Conditions	Corona Loss, Kw Per Kilometer Bundel-Leiter Line	Hollow Conductor Line
Dry	3.5	4.5
Fog	10	22
Rain	28	120

* From British Intelligence Objectives Sub-Committee Final Report number 314, item 33, "The German Electricity Supply System."

Two general lines have been under investigation for the improvement of system stability when affected by long-length transmission lines. Earlier researches were along the lines of transmission-line compensation but this soon was found prohibitively costly with long lines. Recent researches have tended to modify the stability characteristics of the generator. The first method is to produce a-c power with compensated induction generators using rotor excitation with a Scherbius-type system. Model tests have found it feasible to transmit power distances up to 600 miles under both transient and steady-state stability conditions. The second method calls for rapid-excitation response to normal synchronous generators using either series exciters with special features or a more complicated shunt exciter arrangement. Model tests on this system also have produced very satisfactory results. The second method is looked upon as a more satisfactory and economical solution to the problem.

D-c transmission has been found to be applicable in cases of long-distance transmission only. Studies of considerable proportions were undertaken in Germany immediately preceding and during the war resulting in the construction of two d-c lines. Energy transmission was carried out at 400 kv direct current with midpoint grounded. Underground cable was the carrier of the energy and rectifiers and inverters were the media for conversion from alternating current to direct current and vice versa. Opinion seemed divided on the use of mercury-vapor rectifiers versus the Marx high-pressure gas rectifier and one installation using each principle appeared. It seems that the operating results obtained with the mercury-vapor rectifiers were more satisfactory. Sweden also has constructed a d-c transmission line which has been just placed in operation. The concensus of opinion is that, despite the advantages gained with such a system such as lower line loss, better utilization factor, removal of the stability problem, possible use as a frequency-changer tie-in link, removal of the telephone interference problems, and others, d-c transmission, because

Figure 2. Type Re $^4/_4$ locomotive of the Swiss Federal Railway

This unit operates at 15 kv, single phase, $16^2/_3$ cycles per second, and is capable of speeds up to 80 miles per hour of its prohibitive capital cost compared with a-c transmission (several times more costly), cannot be justified except in cases of long-distance transmission with the transfer of a very large block of power (distances above 600 kilometers, and powers of 500 megawatts).

RELAY ENGINEERING

European relaying practice differs in many respects from that in the United States, this being conditioned largely by the European practice of operating with the neutral ungrounded or grounded through Petersen coils.

Germany in particular is equipped with Petersen coil grounding up to 220 kv, the highest voltage in use there. Because 70 per cent of the ground faults are suppressed successfully with this system, such a high standard of protective-gear performance is not necessary as in systems with solid grounding. In other European countries grounding through Petersen coils is popular in the medium voltage ranges up to 60 kv. For higher voltages ungrounded systems are much in vogue except in England where solid grounding is employed at 132 kv, the highest voltage in use, and resistance grounding at lower voltages.

Distance protection of either the impedance or reactance measuring type is in general use for main line protection, usually with the normal stepped characteristic, in some cases as many as five steps being provided. Impedance starting elements are usual, although some equipments are started by voltage drop.

Carrier current protection in Europe has not been developed appreciably other than in England and France. The systems employed so far depend on the directional interlock principle, the stabilizing or locking-out signal being transmitted over the high-voltage line by the carrier equipment. Two systems are also in experimental operation in England in which the current-wave polarity at each end of the protected zone is compared one with the other using the high-frequency link. One operates exclusively with electron tubes while the other uses a telephone-type high-speed relay (operating time less than one millisecond) with dry-plate rectifiers. These new equipments give a relay time of less than one cycle at 50 cycles per second. On the Continent one firm at present is experimenting with carrier distance protection. The carrier equipments themselves usually are operated between line and ground, although line-to-line operation is usual in England, as it has been found to give a better signal-to-noise ratio with the very moderate power of ten watts, the maximum allowable power under the regulations of the British post office governing the use of such equipment. Frequency-modulated equipments are not used.

A very economical form of intertripping system known as fault throwing is to be found in England. It is used for medium-voltage transformer-feeder systems where the transformers at the supply point are resistance-grounded and where no high-voltage circuit breakers are provided on the primary side of the transformers at the receiving end. If a transformer fault arises at the receiving end, making it necessary to trip the circuit breaker at the sending end, an isolator is closed by releasing a weight using an ordinary trip coil, grounding one phase of the line and causing the sending-end circuit breaker to trip on ground leakage.

On pilot-wire systems, intertripping is provided very cheaply by unbalancing the protection by potential or current injection. These arrangements are much used in England.

High-speed neutral ammeters have been developed in England for insertion in transformer neutrals where solid grounding is employed, making the location of ground faults on the line directly possible by reading the neutral currents at each terminal station and determining the fault position from a graph. For line-to-ground faults the location may be determined to within three towers.

Inverse-time and definite-time overcurrent relays are naturally similar to those found in the United States, although a special type, known as a primary relay is unusual. It consists of a combined series overcurrent relay and shaded-pole-motor timing element mounted on the circuit breaker bushing, all parts being alive. Tripping of the circuit breaker is accomplished mechanically by operating the trip latch from the overcurrent element through an insulated rod. These relays are very popular on the Continent because of their low cost and simplicity and ability to operate where no tripping power source is available.

Bus bar protection in Europe is either of the frame leakage or Merz-Price type, often containing check relays in the transformer neutrals where these are grounded. The high-speed relays referred to previously have been used also for this purpose. It now is recognized that high-speed operation is essential for bus bar protection and relay times of one cycle (50 cycles per second frequency) are obtainable with the latest equipments.

Pilot cable (Merz-Price) protection is general for cable networks and these systems do not differ appreciably from those in the United States.

The use of Buchholz relays (gas-operated relays) is general for transformer protection. These devices which are not well known in the United States are connected in the pipe from the conservator to the transformer tank. They have a top float which is operated by accumulation of gas driving out the oil (this float usually sounds an alarm) and a main or surge float which is operated by a transient surge of oil past it. The main float trips the necessary circuit breakers to protect the transformer. Any type of fault, winding or iron, is covered by this device, as well as incipient faults which are detected more rapidly than by any other system. Merz-Price protection is also in use but has decreased in popularity because of the difficulty in making it stable under unsymmetrical switching inrushes. Special winding-temperature thermometers, which are instruments deriving part of their heat from the oil and part directly via a current transformer in the load circuit, are much used to give a true picture of the winding temperature. A special form of this has been devised by the Berlin Supply Authority engineers.

Generator protection is similar to that in the United States. On modern equipment negative-phase-sequence protection often is found and overcurrent relays generally are omitted. Generator voltage regulators are usually of the rolling sector type. Electronic voltage regulators are not known in Europe. Automatic synchronizers are popular in modern continental installations. An electronic synchronizer has been developed in France. Governor control by frequency-sensitive relays is now in use on the Continent and experiments are being made with governor control by wattmeter relays which can be used to hold the load at a constant figure on a specified interchange feeder as desired.

Modern European control rooms use indirectly illuminated mimic diagrams with shadow-type instruments built into the diagram in the appropriate positions. One European firm offers control-room equipment of this type with faultproof interlocking to prevent the fulfillment of switching operations dangerous to the equipment. Such equipment naturally is not cheap. Relays and metering equipment are installed on separate panels behind the control panels to give a very simple, clear, and concise arrangement.

RECTIFIER ENGINEERING

The use of multianode rectifiers in Europe far exceeds that of single-anode rectifiers. In fact, several manufacturers limit themselves exclusively to the manufacture of the multianode type, concentrating their efforts on the reduction of the anode–cathode drop so as to compete with the single-anode type in over-all performance. It is thought that the backfire rate of multianode rectifiers has been reduced to such an extent using improved design techniques and accurate control of the manufacturing processes that its rate compares favorably with that of the single-anode type. Because of the scarcity of raw materials in Europe at the present time, the advantage of less material being used in one multianode tank as compared with many single-anode tanks is an important consideration. The glass-bulb rectifier still is manufactured and continues to be sold in Europe.

The newest developments under way involve the use of better gas seals, thus permitting the manufacture of steel tank "pumpless" rectifiers, air cooling using forced-draft ventilation, especially in the smaller sizes, new transformer connections, and developments involving grid control. A few rectifier-inverter installations using the rectifier as a dual-purpose unit have been made on railroad installations, but the successes of these undertakings have not been outstanding.

Because rectifier engineering is such an empirical field, complete agreement in principles between various manufacturers is lacking. It is difficult to predict future trends because of this. In general it can be said that the applications involving the use of rectifiers parallels those in the United States. However, the production of hydrogen electrolytically is widespread in Europe and requires large amounts of direct current (1,000–8,000 amperes) at low voltages (250–800 volts). Hydrogen is produced from the distillation of coal wherever coal would be used as a source of electric power because it is cheaper to use this method than to produce the electricity for manufacturing hydrogen electrolytically. It must be said, however, that hydrogen produced electrolytically is of the highest purity, a desirable feature when the hydrogen is to be used in the hydrogenation of fats and oils which will be distributed ultimately for human consumption.

ELECTRIC RAILROAD ENGINEERING

All known systems of electric traction are to be found in Europe. Three-phase electric traction has been used a great deal in Italy although no additional installations have been made for some time, and existing systems are being converted to 3,000 volts direct current. Its disadvantages are the complicated twin overhead transmission required for the two phases and the inflexibility of the locomotives which have a maximum of four economic running speeds.

Single-phase low-frequency electric traction is practically universal in Switzerland and Sweden and also is employed to a large extent in Norway, Austria, and Germany. Its advantages are the light catenary construction and the small number of substations required. All speeds are also continuous economic running speeds. Though considerable progress has been made in the design of single-phase series motors, their maintenance is still considerably more expensive and they are more sensitive than an equivalent d-c traction motor. The substation equipment does not differ appreciably from similar 50-cycle substations.

Modern developments in single-phase rolling stock are concerned chiefly with weight reduction and increased power. Following the example of the constructors of high-speed Diesel-electric locomotives in the United States, 2-truck ($B_0 + B_0$) locomotives now are being built for high-speed operation, some of which are of very high power and low weight, namely, Bern Lotchberg Simplon $Ae^4/_4$ locomotive with a one-hour rating of 4,000 horsepower and having a total weight of only 80 metric tons, and the Swiss Federal Railway $Re^4/_4(B_0+B_0)$ locomotive with a one-hour rating of 2,400 horsepower and having a total weight of only 56 metric tons (see Figure 2). These two locomotives are suitable for operation up to 80 miles per hour. The motors are mounted directly in the bogies and drive the axles via quill-drive systems. The one in the BLS locomotive uses a new type of spring-disk coupling requiring no lubrication. Other features are transformers with radially laminated cores and pneumatic thrustor devices pressing on the trucks when starting under different conditions to minimize the effect of weight transfer. The high power ratings of these modern locomotives results in part from the fact that these railways which previously rated their traction motors on the AIEE rules for stationary plant with a 75 degree-centigrade rise in temperature now follow the IEC rules permitting a 125 degree-centigrade rise, thereby increasing the motor output by 40 per cent. Most modern European single-phase locomotives for use in mountainous countries either feature regenerative or resistance braking.

D-c traction is employed in England, France, Holland, Italy, and Spain with voltages from 650 to 3,000 volts. These systems require more substations than the single-phase system but, thanks to the mercury-arc rectifier, these substations can be arranged very simply as unattended plants for automatic or remote control.

In 650-volt d-c traction, which appears only in England as third-rail traction, a new type of flywheel-booster locomotive of C_0+C_0 wheel arrangement has been developed for passenger and freight service on the Southern Railway. This locomotive possesses the necessary flywheel effect to enable it to cross the largest conductor-rail gaps with the heaviest trains without the necessity of a train line and additional collector shoes on the train. All notches on this equipment are running notches. The London Transport System, also a 650-volt d-c conductor-rail system, has placed in service a number of multiple-unit trains with Metadyne control for notchless acceleration. Each Metadyne supplies four traction motors mounted on the cars. The Metadyne, is, in principle, a rotating single armature converter transforming constant voltage input into constant current output and also permits regeneration down to rest.

The French railways, which are electrified using the 1,500-volt d-c overhead system also have built some Metadyne shunting locomotives. They also have built some $2D_02$ express locomotives with the individual driving axles interconnected by gearing to avoid slipping. In one case the arrangement is such that six motors drive four axles, each group of three motors being geared to two axles. This gives the advantage of better spacing of the speed curves for each motor grouping. They also operate a large number of $2D_02$ 4,000-horsepower express locomotives with compensated motors, permitting field weakening down to 25 per cent of full field, thus giving a very large number of running speeds. Most of their express locomotives feature regeneration, the traction motors being separately excited by heavy-current motor-exciter sets embodying an automatic stabilizing feature.

Italy and Poland have the only heavy traction in Europe at 3,000 volts direct current. The Italians have several 2,000-kw mobile rectifier substations mounted on flat cars which can be used to reinforce or replace fixed substations as required. They also use rectifier-inverter groups in the mountainous sections as the locomotives are equipped for regeneration. They intend eventually to replace all their 3-phase electrification by 3,000 volts direct current on the basis of the extremely good results obtained.

The Germans also carried out an experimental 50-cycle per second, 20-kv electrification just before the war on which four types of locomotives were tried. The first was a normal single-phase locomotive with 50-cycle series commutator motors. As the rating per pole is much lower at 50 cycles than at $16^2/_3$ cycles, two motors per axle were used. Two types of rectifier locomotives with full-wave mercury-arc rectifiers and d-c traction motors comprised the second and third types. The Krupp phase-converter locomotive made up the final type in which the conversion took place directly in the traction motors by means of an intermediate rotor located between the stator and main driving slip-ring rotor and energized with direct current.

The French railways also are interested in the use of 50-cycle traction, particularly for local lines where the cost of heavy traction 1,500-volt direct current equipment is not economically justified. They have ordered an experimental single-phase locomotive with 50-cycle series commutator traction motors and a rectifier car for attaching behind the existing 1,500-volt direct current locomotives to enable them to operate from the 50-cycle overhead line. This has a mercury-arc rectifier of the full-wave type and the necessary pantagraphs, transformers, and circuit breakers, and will be of sufficient rating for the existing French B_0+B_0 locomotives.

Lightning-Proof All-Metal Cars and Airplanes

Recent tests at the Westinghouse lightning laboratory in Trafford, Pa., offer reassurance to those who must drive or fly through severe electric storms. Three - million - volt lightning strokes produced by a surge generator were fired at a steel-topped automobile while one of the engineers sat at the wheel, and then at a model Constellation airliner. Both automobile and airplane acted as lightning-proof cages diverting the heavy currents harmlessly around passengers. Although "lightning" struck inches above the engineer's head as he sat in the car, he did not feel the slightest tickle. There was no damage to the car or the airplane except for a small scorched spot on the metal top of the car.

Special Magnetic Alloys and Applications

G. W. ELMEN E. A. GAUGLER
MEMBER AIEE

Superior operating characteristics may be obtained in contact rectifiers and magnetic amplifiers by the use of alloys having rectangular hysteresis loops. Such loops may be produced by drastic cold rolling and final special annealing, or by heat treating in a magnetic field.

ALTHOUGH magnetic materials possessing substantially rectangular hysteresis loops have been known for some time, only recently has this property been utilized in the design of electric apparatus. One of the earliest applications is for saturable reactors used in contact rectifiers. These rectifiers were developed in Germany during the war and have been in commercial use since 1943.

Another application of this type of material is for magnetic amplifiers. Development work on these amplifiers has been under way for some time at the Naval Ordnance Laboratory. The results so far obtained show that superior power output can be obtained when magnetic cores with rectangular hysteresis characteristics are used. While these two are the outstanding applications up to this time, it is believed that when the full significance of rectangular hysteresis loops is appreciated by designers of electric apparatus, many more useful applications will be found, particularly in the design of saturable devices and equipment operated at high flux densities.

MECHANICAL RECTIFIERS

Attempts in the past to construct mechanical rectifiers have been frustrated because of the difficulty encountered in commutation. In order to obtain satisfactory results, the commutation must take place while the current passes through the zero value. In an ordinary a-c wave the rate of change is the greatest at that point. As a result there is no time for commutation without destructive sparking. When saturable reactor coils are put in series with the current leads, a "step" is introduced as the current passes through substantially zero value. This prolongs the time of zero current so that almost sparkless commutation can be obtained. It has been found that far superior results are obtained if these saturable reactor coils have rectangular hysteresis characteristics.

A basic circuit for a 3-phase contact rectifier is shown in Figure 1. The saturable reactor coils are shown together with the windings used to aid in the development of sparkless commutation.

Figure 2 shows the load current (*A*) when the saturable reactors are not in the circuit and (*B*) when they are included as in Figure 1. In the latter part the step in the current wave is shown.

Figure 3 shows the hysteresis loops for two cores of the same material. Core *A* has been heat treated by standard methods and core *B* is specially processed to give a rectangular hysteresis loop. The commutation takes place at the steep portion of the hysteresis loop. When the width of the loop is small the current during commutation will re-

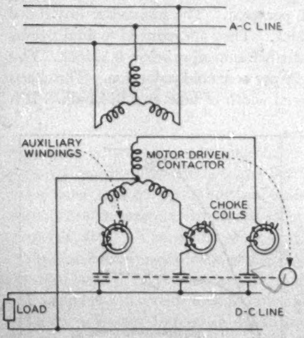
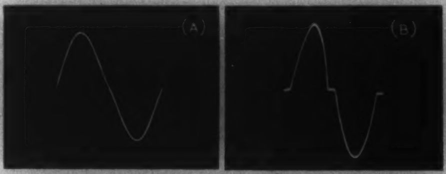


Figure 1. Basic circuit of mechanical rectifier



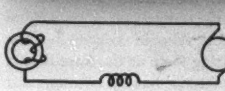


Figure 2. Current oscillograms

A—Without saturable reactor.
B—With saturable reactor using rectangular-hysteresis-loop core material

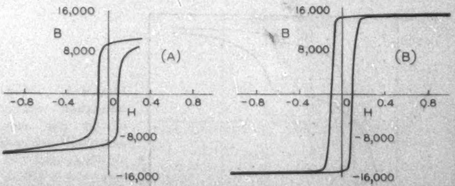


Figure 3. Hysteresis loops of 50 per cent nickel—50 per cent iron alloy having (*A*) standard anneal and (*B*) special anneal after drastic reduction

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Essentially full text of a conference paper "Special Magnetic Alloys and Their Applications," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948.

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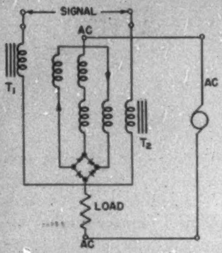

Figure 4. Magnetic amplifier circuit with regeneration

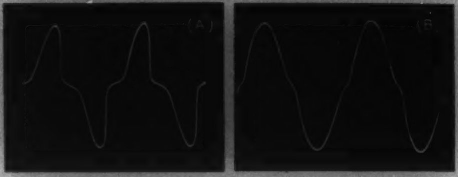

Figure 6. Oscillograms showing output current of magnetic amplifier

A—Using standard core material

B—Using rectangular-hysteresis-loop core material

main small but not zero. In order to reduce the current step to zero an a-c biasing current is supplied through the auxiliary windings. Also, it is desirable that the vertical portions of the hysteresis loops be as steep as possible, and that they approach the saturation value. This extends the commutation interval and minimizes the amount of core material for a given rectifier. Materials which have rectangular hysteresis loop as shown in Figure 2 *B* fulfill these requirements.

Mechanical rectifier units having d-c capacities up to 10,000 amperes and 400 volts have been produced commercially. They are reported to have an over-all efficiency of 97 to 98 per cent.

MAGNETIC AMPLIFIER

Development work at the Naval Ordnance Laboratory has shown that certain advantages in the construction of magnetic amplifiers are obtained by the use of magnetic materials with rectangular hysteresis loops.

One type of magnetic amplifier circuit employing regeneration is shown in Figure 4. Saturable transformers T_1 and T_2 are designed to operate at the knee of the magnetization curve. Because the regeneration is accomplished by the flow of the rectified load current through a feedback winding, a d-c bias is required to minimize the load current at zero signal. When a signal is applied, each transformer is driven into saturation. This increases the magnetizing and load currents.

From power considerations, it is desirable to operate at high flux density. The higher the density at which the knee occurs, the larger will be the output power capacity of a coil with a core of a given size. Also, in order to increase the amplification, the magnetizing force at the knee should be as small as possible. In a material having a rectangular hysteresis loop, the knee occurs very close to saturation value. Because of that, the form factor of the load current more nearly approaches that of a sine wave. Figure 5 shows the magnetization curve of two nickel-iron alloy cores of substantially the same composition. Core *B* has been given a special treatment to produce a rectangular hysteresis loop while core *A* has been given the standard heat treatment. Figure 6 shows the current wave form for each of these cores, showing improved sinusoidal characteristics of the specially treated material. An amplifier constructed with identical cores of these materials delivered over twice as much power when core *B* was substituted for core *A*. Furthermore, the gain is more constant over the entire operating range of the amplifier as shown in Figure 7.

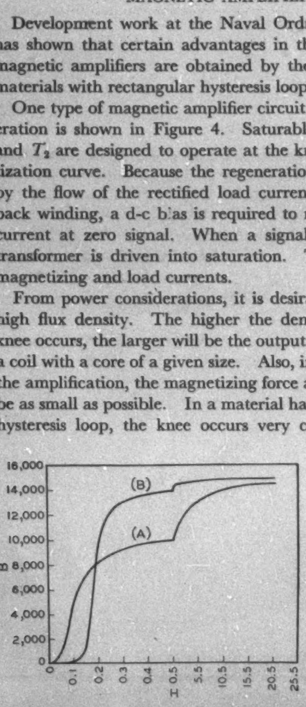

Figure 5. Magnetization curves of 50 per cent nickel–50 per cent iron alloy

A. Standard anneal

B. Special anneal after drastic cold reduction

RECTANGULAR HYSTERESIS LOOPS

One method of fabricating magnetic alloys with rectangular hysteresis loops is by drastic cold rolling and final special annealing. This method was developed for the production of cores for the mechanical rectifier by the Haraeus Vacuumschmelze A.G.

The alloy consisted of equal portions of nickel and iron in which special precautions are taken to reduce impurities both in regard to those introduced by the raw materials and by the melting operations. By melting and casting in vacua and subsequent annealing at high temperatures in pure dry hydrogen, further purification results. By these methods, the oxygen and carbon content of the alloy is reduced below 0.01 per cent. The ingots are hot rolled down to 0.24 inch thick. They are reduced to final size by cold rolling without further annealing below 0.10 inch. This amounts to a 98 to 99 per cent cold reduction. The sheets are slit into the desired width of tape at 0.014 inch. It is

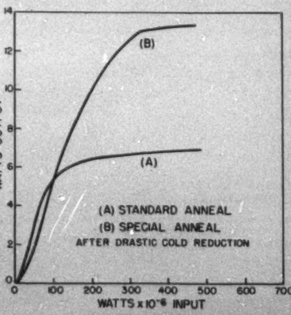

Figure 7. Magnetic amplifier characteristics of 50 per cent nickel—50 per cent iron alloy

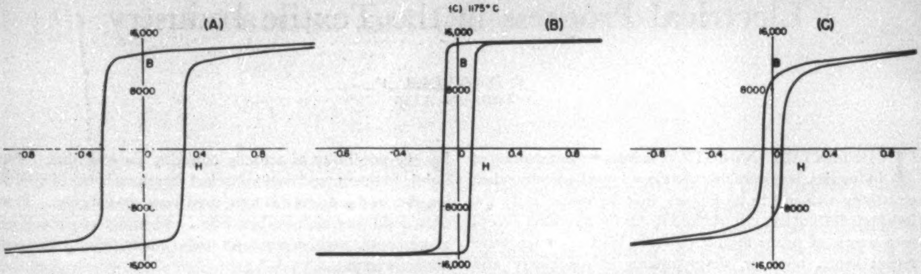

Figure 8. Hysteresis loops of 50 per cent nickel—50 per cent iron alloy

Drastic cold reduction; annealed for 2 hours at (A) 975, (B) 1,100, and (C) 1,175 degrees centigrade

claimed that if the slitting is done after the final rolling the magnetic characteristics are affected adversely.

The final tape either 0.0012 inch or 0.002 inch thick is insulated and wound into spiral cores by standard methods. These cores are heat treated in hydrogen at temperatures between 1,000 and 1,150 degrees centigrade. The charge is loaded into a superheated furnace, held for two hours, and cooled rapidly. The optimum temperature is determined magnetically for each heat using small test samples. Figure 8 shows hysteresis loops of this material annealed under similar conditions at three different temperatures. The alloy represented by curve *C* was annealed at an excessively high temperature and shows magnetic characteristics similar to the standard alloy of the same composition.

Another method of producing rectangular hysteresis loops is by heat treating in a magnetic field. Published reports by Bozorth and others of the Bell Telephone Laboratories show that 69 permalloy and some of the perminvar alloys have rectangular hysteresis loops when cooled in a magnetic field. The result of recent tests at the Naval Ordnance Laboratory on the perminvar alloy containing 7 per cent cobalt, 70 per cent nickel, and 22.4 per cent iron and cooled in a magnetic field is shown in Figure 9.

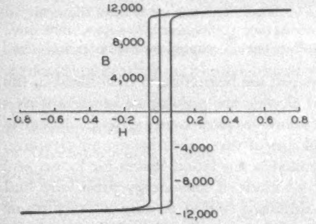

Figure 9. Hysteresis loop of 7-70 perminvar annealed in a magnetic field

Recently Doctor Mihara in Japan has found that if very pure silicon steel is cooled in a magnetic field, rectangular hysteresis loops can be obtained. He was not able to obtain a residual induction as close to saturation as is possible with the other alloys as shown in Figure 10.

CORE DESIGN

In order to utilize these magnetic characteristics in an actual transformer effectively it is essential that certain precautions be taken. Although these fundamentals are well known, they are not considered essential to standard transformer design practice and therefore are not generally adhered to. It is essential that air gaps in the magnetic circuit be minimized in order not to shear over the hysteresis loop. This limits the core design to uncut wound cores or ungapped punchings. Although the fundamental excitation frequency may be low, the transit time during reversal of saturation may be exceedingly short and consequently the specific resistance of the material should be high and the material thickness a minimum. For example, in the mechanical rectifier operating at 50 cycles, the transit time was approximately one millisecond, tape thickness 0.0012–0.002 inch, specific resistance 45 microohm centimeters. Because of difficulties encountered in punching thin material, spirally wound cores are preferred.

Other precautions must be taken in order to obtain a sharp knee in the magnetization curve. One is that the magnetizing force be uniform over the entire cross section of the core. This implies a relatively narrow annular width. Another is that after the final heat treatment care must be taken to prevent mechanical strains. These cores therefore are mounted in annular aluminum troughs with plastic covers to support the windings.

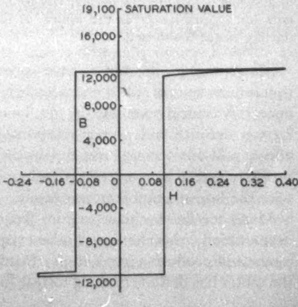

Figure 10. Hysteresis loop of high purity 5 per cent silicon iron cooled in a magnetic field of 0.3 oersted

Electrical Progress in the Textile Industry

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THE TEXTILE INDUSTRY, being one of the oldest of industries, was so highly developed mechanically when electricity was still in its infancy that for many years the industry did not use electric apparatus for anything except as a source of prime motive power. Within comparative recent years, however, developments in machinery and processes have been rapid. With the new machinery and processes it is natural that many electrical means are employed to perform functions previously performed mechanically. There are a number of basic electric tools that are now employed in various combinations to get many desired results in machine operation and performance. It is the purpose of this article to list and describe a number of these and also to show how they are used to get improved textile machine performance.

Many textile machines require controlled acceleration to protect the machine or to protect the material in process. For their normal operation, however, the motor may be a simple squirrel cage motor. For such applications several forms of starting equipment are in use.

1. A single block of resistance is placed in the power supply line during the starting period. The amount of resistance can be adjusted to provide just the correct starting torque. On most of such applications the control is arranged to short circuit out the resistance automatically when the motor has reached about 90 per cent of its full speed. Roving frames, spinning frames, twisters, and winders, are examples of machines using this type of starting.

2. Some machines, as for example woolen cards, require a high torque applied gradually to break starting friction and then have comparatively slow acceleration to avoid mechanical damage to the machine. To achieve such results resistance-type starters are used which automatically build up the motor torque from a very low value up to a value sufficient to start the machine and then again reduce the torque to continue acceleration at a slow smooth rate.

3. Controlled acceleration also may mean a very high and rapid acceleration such as is required on shuttle-type looms and warp knitting machines. For such machines a motor that has the proper and best characteristics to run the machine continuously does not have sufficient starting torque to give the rapid acceleration required. This has been overcome by providing a control which will connect the motor delta for starting and Y for running. This gives the effect of applying 1.73 times the normal voltage and since starting torque goes up approximately as the square of the voltage a very high starting torque is obtained.

Many textile machines have operating requirements that require special motor characteristics to get best performance. A typical example is the loom motor which must have a definite and proper relationship between flywheel effect, pull-out torque, and slip in order to run the loom properly and to have a motor which operates efficiently and with the lowest possible power input.

Many textile machines require frequent and very rapid deceleration. Mechanical brakes require much maintenance and produce a harsh stop. Putting reverse power on the motor has definite braking torque limitations and always has the possibility of actually reversing the machine. For quick, frequent, and rapid deceleration the scheme of applying d-c to a-c motors is now used very extensively. This provides a very high braking effect and brings any machine to a smooth, positive stop and under no conditions can the motor reverse.

For exceedingly fast stops a system of control has been developed which changes the motor from running with a-c applied to d-c applied through metallic rectifier by merely opening one contactor. With this scheme stopping a 1750-rpm motor in less than two revolutions is entirely possible, which is in the order of 0.06 second. It requires as much or more time to apply or start the braking action with mechanical or a-c plugging means.

Within recent years variable speed drives have been applied to many machines and processes. There are many types available and all have properties which make them the most economical for certain requirements.

1. Slip-ring-type a-c motors. This type of motor is used extensively where a speed change of not over two to one is required and where exact speed with load variation does not have to be maintained.

2. D-c motors of the series type with a series-type generator have an excellent characteristic of providing high momentary slip with rapid load increase and provide a smooth drive for such machines as the Axminster carpet loom. It also provides speed variations of ten to one and a simple means of getting very high dynamic braking.

3. D-c motors of the shunt field type with variable voltage generators are used extensively, especially for machines and processes where two or more motors are run in range. This method of drive allows the use of Rototrol (rotary regulator), tachometer generators, and other devices to maintain accurate tension or speed control between sections.

Electronic devices just are beginning to be utilized in the textile industry and already are proving an important new tool in such applications as yarn twist setting, dielectric heat for drying packages of yarn, electrostatic air cleaning, electronically controlled beam let-off drives for looms and knitting machines, all kinds of low-energy drop wire and feeler controls for initiating action to stop a machine or make some transfer of action. The list of electronic applications is growing daily.

Electrical progress in the textile industry has been such that today the industry rapidly is changing from a purely mechanical one to an industry that uses many and varied electric devices to perform the delicate and intricate functions of more and more of its machines. Close co-operation between textile mills, textile machinery builders, and electrical manufacturers will produce results that will make better textiles and textile products available to all.

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Induction and Dielectric Heating

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INDUCTION and dielectric heating have assumed in recent years an important position in industrial heating; dielectric heating more recently than induction. These unique forms of heating, once responsible only for power losses in electric equipment and machinery, offer many advantages over conventional means of heating by convection, conduction, and radiation. The field of application is very broad because induction heating is suited to metals, particularly those that have a high magnetic permeability, and dielectric heating may be accomplished in a large class of thermally insulating materials which at low frequencies are also electrically insulating.

Induction heating is effected simply by ohmic losses in the charge produced by eddy currents induced from a work coil receiving energy from a suitable source. The energy dissipated in the source may be expressed approximately by the equation:

$$P=\frac{8\pi H_0^2}{\sigma}\cdot\frac{r}{d}$$

where

P = energy in watts per unit length
H_0 = impressed magnetic field in ampere turns per centimeter
σ = conductivity of charge in ohms per (centimeter)^3
r = radius of charge in centimeters
d = depth of penetration of heating in centimeters

The depth of penetration of the heating in the charge is inversely proportional to the frequency of the power source. The useful upper limit of frequency is limited by this fact to the order of a few megacycles. The particular advantages of induction heating over conventional methods are

1. Very great speed—power inputs up to 80 kw per square inch.
2. Precisely controllable.
3. Differential heating possible.
4. Convenience.
5. Contact not necessary—continuous process.
6. Heat generated only in charge.

These advantages make possible in many instances cost reduction and quality improvement in heating operations such as:

1. Melting—flow of tinplate.
2. Annealing.
3. Heat treating.
4. Surface hardening.
5. Outgassing vacuum tubes.
6. Soldering and brazing.

Dielectric heating results when a charge is placed within the influence of an alternating electric field. The actual power dissipation is produced largely by the orientation of the dipolar molecules of the charge in the electric field. For a charge of uniform cross section placed between plane parallel electrodes the energy dissipated may be expressed:

$$W=5/9k\tan\delta\left(\frac{E}{d}\right)^2\times10^{-12}$$

in which

W = heat generated in watts per (centimeter)^3
k = dielectric constant of charge
$\tan\delta$ = dissipation factor of charge
f = frequency of power source in cycles per second
$\left(\frac{E}{d}\right)$ = voltage gradient between electrodes in volts per centimeter

Below one megacycle the dielectric heating effect is negligible and above 30 megacycles serious operating limitations are encountered so that 10–30 megacycles is the optimum frequency range for large-scale industrial dielectric heating. The outstanding advantages of dielectric heating are

1. Rapid heating cycles—materials conventionally requiring hours are heated in as many minutes.
2. Heat generated uniformly throughout volume, resulting in correspondingly uniform temperature provided certain precautions are taken.
3. Precise control of heating possible.
4. Class of materials suited to dielectric heating (electrical and thermal insulators) most unsuited to conventional means of heating.

These advantages have resulted during the past ten years in dielectric heating becoming firmly established in plastic molding, plywood and furniture bonding, rubber processing, textile, and food industries.

Certainly induction and dielectric heating should play an important part in the industrialization of Mexico. The electric power is available, or will be soon, and many of the industries now in existence or planned for Mexico are those that can employ high-frequency heating profitably. Mexico will have the advantage that induction and dielectric heating equipment may be installed initially in new factories as they are built rather than be installed to replace and therefore make obsolete conventional heating equipment, as frequently has been the case in the United States. Although the capital investment for induction and dielectric equipment will be greater than that required for conventional heating equipment, the use of the former certainly will result in higher rates of production and improved quality with fewer rejects. A high level of production will allow product prices to be set lower than otherwise would be possible, which in turn will tend to improve the standard of living throughout Mexico.

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Doubly Chorded Fractional-Slot Windings

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THE PATTERN MOSTLY USED for laying out balanced fractional-slot windings is that for maximum distribution factor of the main wave. From this pattern, a large number of other balanced patterns can be obtained by a cyclic shifting of coils from one phase to the other inside the same repeatable group. The distribution factor of the main wave of these latter patterns is always smaller than that of the former pattern. The distribution factors of the harmonics are partially smaller, partially larger than those of the former pattern, so that the values of the harmonic (differential) leakage reactance of the different patterns do not differ much from each other. The advantage of the pattern with cyclic shift of coils inside the same repeatable group is that it makes possible to reduce the distribution factors of one or several undesirable electromotive force or magnetomotive force harmonics. The aim of this article is to show that the same effect of reduction of certain harmonics can be achieved by shifting of repeatable groups with respect to each other. This method of reduction of harmonics has the advantage that it is applicable to lap as well as to wave windings while the cyclic shift of coils is limited to lap windings. Further, the shift between the repeatable groups, necessary to achieve desirable results, is seen immediately, while with the cyclic shift of coils inside the same repeatable group the trial-and-error method is to be applied. On the other hand, the shifting of repeatable groups reduces the maximum possible number of parallel circuits.

The normal chording of a winding is nothing else than a shift of the lower layer with respect to the upper layer. When repreatable groups are shifted with respect to each other, the fractional-slot winding becomes doubly shifted or doubly chorded and two pitch factors are to be considered.

In many practical cases, it becomes necessary to reduce several harmonics simultaneously. In these cases, the double chording and cyclic shift of coils can be combined.

Figure 1 shows the slot-star of a 3-phase 20-pole lap winding with $q=N/\beta=17/5$. There are 17 slots per phase in 5 poles. For maximum distribution factor of the main wave, the first 17 slots are assigned to phase A, the following 17 slots to phase C, and the last 17 slots to phase B. The slots assigned to phase A are indicated by crosses, those assigned to phase C by rectangles, and those assigned to phase B by circles.

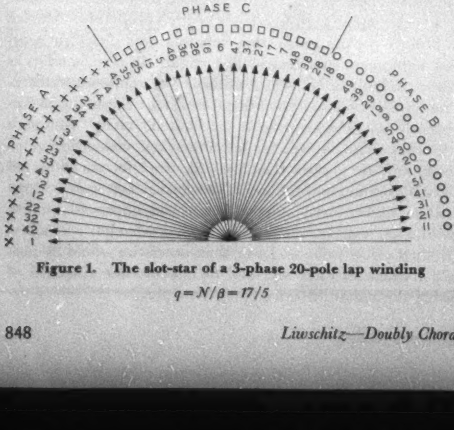

Figure 1. The slot-star of a 3-phase 20-pole lap winding

$q=N/\beta=17/5$

The vectors of the slot-star follow the series

$$1,\ 1+d,\ 1+2d,\ 1+3d,\ \ldots \qquad (1)$$

where

$$d=\frac{3NP+1}{\beta}$$

P is the smallest integer which makes d an integer. For the winding of Figure 1, $d=41$. With the value of d fixed, the slots assigned to the three phases can be determined without drawing the slot star. The d-series yields the following slots for phase A in the first repeatable group

1, 42, 32, 22, 12, 2, 43, 33, 23, 13, 3 44, 34, 24, 14, 4, 45

There are $20/5=4$ repeatable groups in the winding. When there is no shift between the repeatable groups, the following slots are assigned to phase A in the second repeatable group

52, 93, 83, 73, 63, 53, 94, 84, 74, 64, 54, 95, 85, 75 65, 55, 96

In order to produce a shift of the second repeatable group with respect to the first repeatable group of, for example, three slot-star angles, the following slots are to be assigned to phase A in the second repeatable group

73, 63, 53, 94, 84, 74, 64, 54, 95, 85, 75, 65, 55, 96, 86, 76, 66

That is, in the second repeatable group, the first three slots of phase C are to be assigned to phase A, the first three slots of phase B are to be assigned to phase C, and the first three slots of phase A to phase B. The same applies to the fourth repeatable group with respect to the third. If in the winding considered, for example, the 1.4th harmonic (with respect to the main wave as fundamental) is to be reduced, the shift of repeatable groups by three slot-star angles introduces for this harmonic a pitch factor which equals 0.182, that is, the harmonic is reduced by 82 per cent.

Because the influence of the shift of repeatable group appears in the form of a pitch factor, all harmonics are reduced by this shift. With the cyclic shift of coils within the same repeatable group, a part of the harmonics is decreased while the other part is increased.

Digest of paper 48-163, "Doubly Chorded or Doubly Shifted Fractional-Slot Lap and Wave Windings," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE North Eastern District meeting, New Haven, Conn., April 28–30, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Primary Detectors for Measurements

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The basic elements of any measurement system may be classified into three functional groups known as primary detectors, intermediate means, and end devices. By classifying the primary detectors for both electrical and nonelectrical quantities, convenient selection of a suitable detector may be made when the quantity to be measured together with the range over which it will vary is known.

IN VIEW of the growing importance of measurements to technical progress, it is surprising that only limited attention has been given to a complete functional analysis and classification of the whole measurement field. One excellent step in that direction has been made. In essence, this consists of classifying the basic elements of any measurement system into three functional groups known as the primary detectors, the intermediate means, and the end devices.[1-3] These groups are shown schematically in Figure 1 and each group may be composed of one or more sets of measurement components called basic elements. Each basic element may operate with others in series or in parallel or in any complex manner.

This article is written as the result of a more detailed study of the functional groups just mentioned and will lead to a more complete realization of the advantages of the over-all analysis. A method of treating and analyzing one particular group of any measurement sequence is presented in a novel and useful manner. The first group, the primary detectors, is discussed in this article. This investigation results in a method of classification which is suitable for choosing the primary detector best adapted for measurement of a particular quantity. It serves as a guide toward effectual further study of obtainable accuracies and it indicates other detectors which might be used as substitutes. It also presents a standardized method of analyzing any primary detector, a method which will result in a practical understanding of both the steady state and transient operation of this part of the measuring system.

The primary detector in a measurement system has been defined as the first basic element or group of elements that responds quantitatively to the quantity measured and performs the initial measurement operation. For example, in a simple measurement of radio-frequency current, it consists of a thermocouple converter as shown in Figure 2. In a more complex system, the detector may be a separate device such as the a-c generator of a railway tachometer, as illustrated in Figure 3. Moreover, a primary detector may be a relatively simple unit such as a thermocouple, or more complex as in the case of a watt-hour meter mechanism.

CLASSIFICATION OF PRIMARY DETECTORS

Applications of primary detectors naturally fall into two classifications: (*a*) those used in measuring electrical quantities, and (*b*) those used in measuring nonelectrical quantities. Typical results of such classifications are shown in Tables I and II.

These tables are arranged in a form convenient for the selection of a suitable detector when the quantity to be measured together with the range over which it will vary is known, since these are the first two columns in the tabulation. In using the tables it should be understood that the "range of measurement" applies to the order of magnitude with readily available detectors and may be extended considerably for special applications using detectors specifically designed for such use. The range in many cases is shown from zero to a specified maximum and this indicates that instruments with scales indicating down to zero are available. The minimum limit of measurability in such cases depends on the sensitivity of the instrument and the allowable accuracy for the application.

The third column of Tables I and II lists a common name for the detector and this is followed by the basic elements used in the construction of the primary detector in the fourth column.

The action of the detector is described by the next three columns headed the input, the physical effect, and the output, respectively. The last column names one particular instrument in which the application of the primary detector is adequately illustrated. In most cases several other available instruments might have been used equally well to show the application of the primary detector.

A careful study of the tables together with a visualization of possible intermediate means and end devices will demonstrate the value and benefits which can be derived from such information. For instance, when it is known that accuracy requirements will dictate a servomechanical system, a primary detector suitable to this application can be selected. It is realized that the tables do not cover all the primary detectors used in measurements. It is believed that they include most of the detectors widely used in common applications. Undoubtedly additions to the tables in the future will keep them up to date with respect to new detectors which may be invented and also add to their usefulness.

Full text of paper **48-104**, recommended by the AIEE instruments and measurement committee and approved by the AIEE technical program committee for presentation at the AIEE Great Lakes District meeting, Des Moines, Iowa, April 1–3, 1948. Manuscript submitted November 13, 1947; made available for printing February 26, 1948; scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Among the authors' associates who have contributed to this study of primary detectors are I. F. Kinnard (F'43) and H. C. Dickinson (A'37). F. E. Arnold was particularly helpful in the collection of data for Tables II and III.

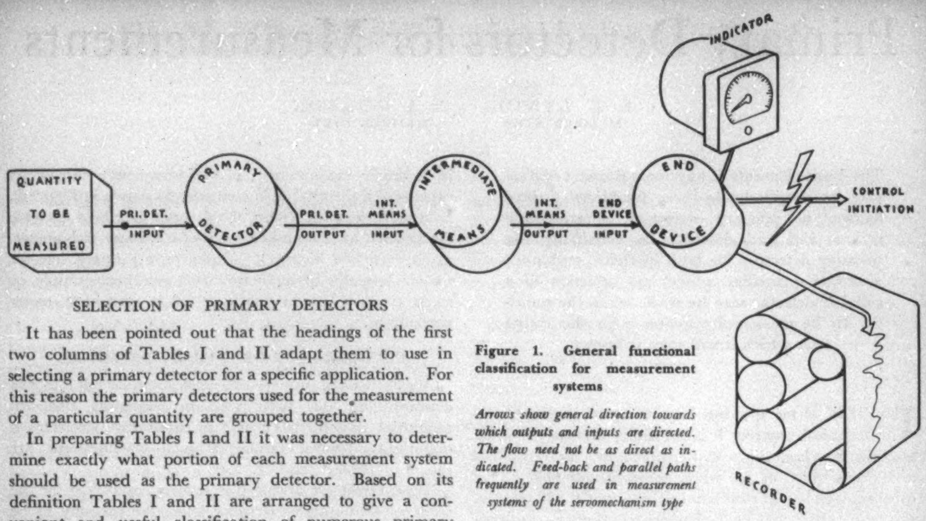

QUANTITY TO BE MEASURED
PRI. DET. INPUT
PRIMARY DETECTOR
PRI. DET. OUTPUT
INT. MEANS INPUT
INTERMEDIATE MEANS
INT. MEANS OUTPUT
END DEVICE INPUT
END DEVICE
INDICATOR
0
CONTROL INITIATION
RECORDER

Figure 1. General functional classification for measurement systems

Arrows show general direction towards which outputs and inputs are directed. The flow need not be as direct as indicated. Feed-back and parallel paths frequently are used in measurement systems of the servomechanism type

SELECTION OF PRIMARY DETECTORS

It has been pointed out that the headings of the first two columns of Tables I and II adapt them to use in selecting a primary detector for a specific application. For this reason the primary detectors used for the measurement of a particular quantity are grouped together.

In preparing Tables I and II it was necessary to determine exactly what portion of each measurement system should be used as the primary detector. Based on its definition Tables I and II are arranged to give a convenient and useful classification of numerous primary detectors.

An example such as the permanent-magnet moving-coil mechanism (Table I) illustrates a criterion for determining which of the basic elements of a measurement sequence constitutes the primary detector. This mechanism basically detects current. The first complete measurement operation consists of the effects up to and including the production of torque. Thus, in a simple d-c ammeter the primary detector consists of the moving coil and the permanent magnet which together produce the torque. Sometimes this torque terminates in angular displacement of a spring controlled moving system. In other applications the countertorque is electrodynamic with no definite torque–deflection characteristic. For this reason the functional output of the permanent-magnet moving-coil mechanism is torque rather than deflection.

This same mechanism is also useful in measuring direct voltage. A resistance is used in series to obtain a suitable current magnitude. The operation in going from voltage to current by means of the impedance of the resistor is not considered a complete operation. This is a matter of convenience. The nature of voltage and current is so closely allied that the resistor together with the permanent-magnet moving-coil mechanism is classified as the primary detector, with torque as the output. Similar combinations of resistance or impedance networks are used with electrodynamic and other detectors.

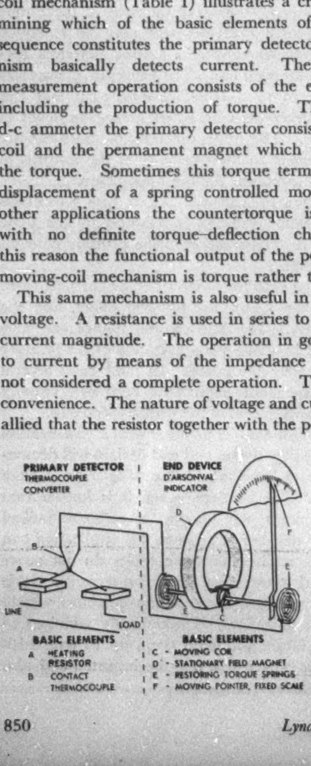

PRIMARY DETECTOR
THERMOCOUPLE CONVERTER
END DEVICE
D'ARSONVAL INDICATOR
A
B
C
D
E
E
F
LINE
LOAD
BASIC ELEMENTS
A HEATING RESISTOR
B CONTACT THERMOCOUPLE
BASIC ELEMENTS
C - MOVING COIL
D - STATIONARY FIELD MAGNET
E - RESTORING TORQUE SPRINGS
F - MOVING POINTER, FIXED SCALE

Figure 2. Radio-frequency ammeter

There are other examples where the permanent-magnet moving-coil mechanism is used in a measurement sequence but not as the primary detector. In the light meter (Figure 4), the nature of the cell output is so different from the input that the cell automatically falls into the classification of the primary detector.

THE INPUT

The primary detector as shown in Figure 1 has a functional input and a functional output. These quantities are not to be confused with the power or energy input and output which are the cause and result of the primary detector's operation. For example, in Figure 3 the railway tachometer primary detector is an a-c generator with a power input and output expressable in horsepower or kilowatts. However, the functional input is speed and the functional output is voltage.

The measured quantity is often, but not always, the input to the primary detector. Cases where it is not convenient to consider the measured quantity as the input are as follows:

(*a*). When the measured quantity is represented by several component quantities and these components are used as inputs. The thermal watt demand meter, Figure 5, includes a primary detector for a-c power where alternating potential and current, phased according to their power factors, are the inputs.

(*b*). When a factor of the measured quantity is introduced elsewhere in the measurement sequence such as shown in the single-phase var-hour meter, Figure 6. Var-hours is the measured quantity, and

Table I. Typical Primary Detectors for Measurement of Electrical and Magnetic Quantities

	Quantity Measured	Range of Use	Name	Basic Elements	Input	Physical Effect Output = Kf (Input)	Output	Typical Application
1	Direct current	From 0 to 1 amp	D'Arsonval mechanism	Permanent magnet and moving coil	Direct current	The field of the magnet produces a torque on the current carrying conductors of the moving coil.	Torque	D-c ammeter
2	Direct current	From 0 to 10 amp	Moving magnet mechanism	Fixed coil moving permanent magnet	Direct current	The magnetic field of the fixed coil produces a torque on the moving magnet.	Torque	D-c ammeter
3	Direct potential	From 0 to 5,000 v	D'Arsonval mechanism	Permanent magnet, moving coil, and resistor	Direct potential	The potential, applied to a calibrated resistor, results in current $I=E/R$ which is measured as in (1).	Torque	D-c voltmeter
4	Direct potential	From 0 to 100 v	Moving magnet mechanism	Fixed coil, moving permanent magnet, and resistor	Direct potential	The potential, applied to a calibrated resistor, results in a current $I=E/R$, which is measured as in (2).	Torque	D-c voltmeter
5	Alternating or direct current	From 0 to 600 amp	Moving-iron mechanism	Fixed coil and ferromagnetic vane	Current	The magnetic field of the fixed coil induces magnetic poles in the moving vane causing attraction or repulsion.	Torque	A-c or d-c ammeter
6	Alternating or direct current	From 0 to 100 amp	Thermocouple	Resistor and thermocouple	Current	The current heats the resistor, the temperature rise of which produces electromotive force at the junction of 2 dissimilar metals.	Potential	Thermoammeter
7	Alternating or direct current	From 0 to 1.0 amp	Electrodynamic mechanism	Fixed coil and moving coil	Alternating or direct current	The magnetic fields of the fixed and moving coils interact to produce a torque.	Torque	A-c or d-c ammeter
8	Alternating or direct potential	From 0 to 750 v	Moving-iron mechanism	Fixed coil, moving iron, and resistor	Alternating or direct potential	The potential, applied to a calibrated noninductive resistor, results in a current $I=E/R$, which is measured as in (5).	Torque	A-c or d-c voltmeter
9	Alternating or direct potential	From 0 to 750 v	Electrodynamic mechanism	Fixed coil, moving coil, and resistor	Alternating or direct potential	The potential applied to a calibrated noninductive resistor, results in a current $I=E/R$ which is measured as in (7).	Torque	A-c or d-c voltmeter
10	Frequency	From 0 to 1000 c	Resonant circuit	Fixed inductors and fixed capacitors	Potential of variable frequency	The current–voltage relationship in the resonant circuit is a measure of the frequency.	Current or voltage	Frequency meter
11	A-c or d-c power	From 0 to 450 kw	Electrodynamic mechanism	Fixed coil, moving coil, and resistor	Current and potential	The magnetic fields of one fixed and one moving coil interact to produce a torque proportional to their instantaneous product.	Torque	Wattmeter
12	Power factor	From 0 to 1.00	Electrodynamic mechanism	Fixed coil, 2 moving coils, fixed resistor, and fixed inductor	Current and potential with variable power factor	The magnetic fields of one fixed and two moving coils interact to produce angular displacement when power factor is changed.	Angular displacement	Power factor meter
13	Energy (a-c)	From 0 to 10,000 kwh at rates up to 90 kw (600 v, 150 amp)	Watt-hour meter mechanism	Electromagnet, braking magnet, and eddy-current disk	Current and potential	The reaction of fluxes of the electromagnet with eddy currents induced in the disk by these fluxes produces a torque. This torque, when opposed by the braking torque of the permanent magnet, results in angular disk displacement proportional to energy.	Angular displacement	Watt-hour meter
14	Reactive energy (a-c)	From 0 to 10,000 rkva hr at rates up to 90 rkva (600 v, 150 amp)	Watt-hour meter mechanism and phase shifting transformer	Phase shifting transformer, electromagnet, braking magnet, and eddy-current disk	Current and phase-displaced potential	Same as (13)	Angular displacement	Reactive volt-ampere hour meters
15	Power demand	From 0 to 24 kw	Bimetallic actuator	Bimetallic actuators	Current	Input currents from voltage and current sources are combined in opposing bimetallic spirals to produce displacement as a function of power.	Angular displacement	Thermal watt demand meter
16	Energy (d-c)	From 0 to 10,000 kwhr at rates up to 9,000 kw (750 v, 12,000 amp)	D-c watt-hour meter mechanism	Fixed air-core coil, moving air-core coil, commutator eddy-current disk, and braking magnet	Current and potential	The magnetic fields of the fixed and moving coils interact to produce a torque. This torque when opposed by the braking torque of the magnet and disk, results in angular displacement proportional to energy.	Angular displacement	D-c watt-hour meter
17	Phase angle	From 0 to 360 deg	Phase angle meter mechanism	Electromagnetic stator, fixed coil, ferromagnetic vane, fixed resistors, and fixed capacitors	Two potentials	The interaction of magnetic fields due to two potentials causes displacement of the moving vane as a function of the phase angle.	Angular displacement	Phase angle meter (synchroscope)
18	Resistance	From 1 to 100×10^8 ohms	Permanent magnet moving coil mechanism	Permanent magnet, moving coil, and constant voltage source	Resistance	The constant potential applied to the resistance under measurement produces current flow $I=E/R$ which is measured as in (1).	Torque	Ohmmeter

Table I (Concluded). Typical Primary Detectors for Measurement of Electrical and Magnetic Quantities

	Quantity Measured	Range of Use	Name	Basic Elements	Input	Physical Effect Output = Kf (Input)	Output	Typical Application
19	Resistance	0.01×10^{-6} to 10×10^{6} ohms	Resistance bridge including galvanometer	Fixed resistors, variable resistors, voltage source, permanent magnet, and moving coil	Resistance	A resistance change in a balanced bridge network causes a galvanometer deflection, which results in adjustment of variable resistors to re-establish bridge balance.	Mechanical displacement	Resistance bridge
20	A-c magnetic flux		Search coil	Search coil	A-c flux linkages	The flux linkages induce a potential in the coil. This potential is a function of the rate of change of flux.	Potential	Flux voltmeter
21	D-c magnetic flux		Moving search coil	Search coil and means of motion	D-c flux linkages	The moving search coil is the source of a quantity of electricity proportional to the change in flux linkages.	Quantity of electricity	Ballistic fluxmeter
22	Magnetic field strength		Moving magnet	Moving magnet	Field strength	The field exerts a torque on the magnet as a function of this field strength.	Torque	Magnetometer

time (hours) is introduced by the integrating function of the detector. The inputs are properly phased alternating potential and current and the output is the angular position of the disk.

THE OUTPUT

The functional output of the primary detector energizes or controls the operation of the end device. The output may be the input to an end device directly as shown in the radio-frequency ammeter, Figure 2, or it may be the input to an intermediate means as shown in the tachometer, Figure 3. The output of an ideal primary detector should bear an exact relation to the steady-state condition of the input. As an example, the output of a watt-hour meter mechanism (Figure 6) when measuring var-hours must be angular deflection. This is the first quantity that represents quantitative response to var-hours. The torque of the driving element is proportional to vars but not to var-hours. Torque, therefore, cannot be the output. The input–output relationship, Figure 7, must be repeatable within the required precision of measurement. This precision must be sustained in most cases over long periods of time.

If the measured quantity varies rapidly, the output inherently will contain additional transients. At times such action is desirable. A thermal watt demand meter, such as shown in Figure 5, utilizes the thermal capacity and heat insulation characteristics of the primary detector to obtain the desired transient or lagged response. In the radio-frequency ammeter, shown in Figure 2, the heat constants are so chosen that the output response is slow compared to radio-frequency cyclic changes of the input. Only the rms value of the current appears in the output. The lagging characteristics of the detector thus are utilized advantageously.

Transients also occur at times when they are undesirable. In such cases the magnitude or time constants of the transient must be negligible. If it is impossible or not feasible to accomplish this, the primary detector is unsuitable for measurement of rapidly varying quantities. Since electric networks (due to their impedance) and mechanisms (due

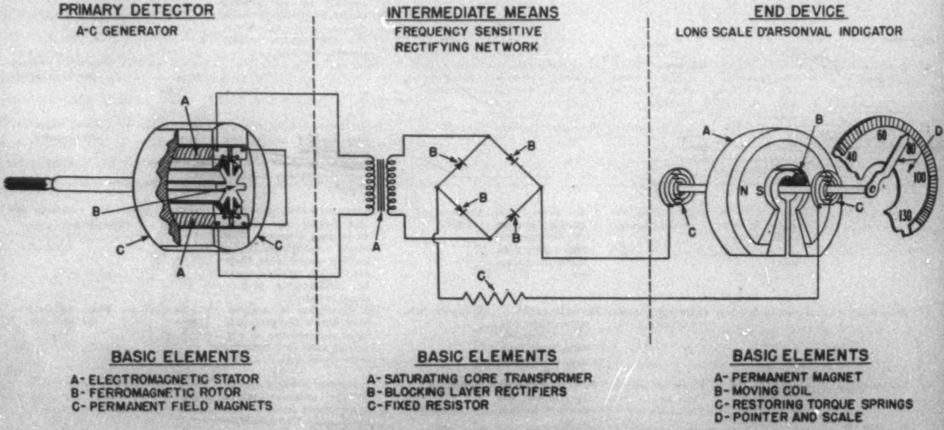

PRIMARY DETECTOR
A-C GENERATOR
INTERMEDIATE MEANS
FREQUENCY SENSITIVE
RECTIFYING NETWORK
END DEVICE
LONG SCALE D'ARSONVAL INDICATOR
A
B
C
C
A
A
B
B
B
B
C
A
B
C
C
D
N
S
40
60
80
100
130
BASIC ELEMENTS
A- ELECTROMAGNETIC STATOR
B- FERROMAGNETIC ROTOR
C- PERMANENT FIELD MAGNETS
BASIC ELEMENTS
A- SATURATING CORE TRANSFORMER
B- BLOCKING LAYER RECTIFIERS
C- FIXED RESISTOR
BASIC ELEMENTS
A- PERMANENT MAGNET
B- MOVING COIL
C- RESTORING TORQUE SPRINGS
D- POINTER AND SCALE

Figure 3. Railway tachometer system

Table II. Typical Primary Detectors for Measurement of Nonelectrical Quantities

	Quantity Measured	Range of Use	Name	Basic Elements	Input	Physical Effect Output = Kf (Input)	Output	Typical Application
1	Temperature	From −200 C to 1,700 C	Thermocouple	Thermocouple	Temperature	An emf exists at the junction of dissimilar metals. A temperature difference at two junctions results in a potential difference.	Potential	Thermocouple thermometer
2	Temperature	From −240 C to 600 C	Resistance temperature detector	Temperature sensitive resistor	Temperature	Electrical resistance changes with temperature.	Resistance	Resistance thermometer
3	Temperature	From 800 C to 2,000 C	Disappearing filament	Incandescent filament lamp and d-c source	Temperature	Light emitted from a glowing body depends on temperature and its intensity can be matched visually against an adjustable standard such as the filament of an incandescent lamp.	Light intensity	Disappearing filament optical pyrometer
4	Temperature		Phototube	Photo sensitive cell	Temperature	Light emitted from a glowing body depends on temperature and can be used to actuate a photosensitive cell, the resistance of which, as a circuit element, is a function of temperature.	Effective resistance	Automatic optical pyrometer
5	Temperature	From 500 C to 2,000 C	Thermopile	Radiation thermocouple	Temperature	Radiant heat from a hot body alters the temperature of a thermojunction so that the thermocouple potential difference is a function of temperature.	Potential	Radiation pyrometer
6	Temperature	From −100 C to 400 C	Bimetallic actuator	Bimetallic actuator	Temperature	Two joined metal strips with different expansion coefficients will bend as temperature changes.	Mechanical displacement	Bimetal thermometer
7	Temperature	From −190 C to 500 C	Liquid-in-glass expansion bulb	Liquid-in-glass expansion bulb	Temperature	Most materials expand with temperature increases.	Mechanical displacement	Mercury thermometer
8	Temperature	From −60 C to 550 C	Fluid-in-metal expansion bulb	Fluid-in-metal expansion bulb	Temperature	Expansion of liquid or gas due to temperature rise increases pressure in a completely filled system.	Pressure	Bourdon tube thermometer
9	Temperature	From −25 C to 325 C	Vapor - pressure bulb	Vapor - pressure bulb	Temperature	In a partially filled liquid system the vapor pressure is a function of the temperature.	Pressure	Temperature controller
10	Pressure	From 0 to 10,000 lb per sq in.	Bourdon tube	Bourdon tube	Pressure	Expansion of liquid or increase in gas pressure in a curved closed tube tends to straighten it.	Mechanical displacement	Bourdon pressure gauge
11	Pressure	From 0 to 500 lb per sq in.	Bellows or diaphragm	Bellows or diaphragm	Pressure	Increased pressure inside a flexible bellows or diaphragm tends to expand it.	Mechanical displacement	Aneroid barometer or altimeter
12	Pressure	From 0 to 20 lb per sq in.	U tube	Liquid column	Pressure	Increased head in one leg of a U tube with liquid in it displaces the liquid.	Mechanical displacement	Manometer
13	Pressure	From 10 to 2,500 lb per sq in.	Piston	Piston	Pressure	A piston with a pressure on one end will move. When balanced by pressure on the other end, the balancing force is a function of the pressure.	Force or weight	Dead weight tester
14	Pressure	From 0 to 1,500 lb per sq in.	Piezoelectric crystal	Piezoelectric crystal	Pressure	Stress causes strain in a crystal and strained crystals become electrically polarized.	Potential	Crystal-type pressure gauge
15	Vacuum	From 0.1 to 2,000 microns	Calibrated volume system	Volume and piston	Pressure	A known volume of gas at a given pressure will compress to a new measurable volume at a known pressure. $pv=c$	Mechanical displacement	McLeod gauge
16	Vacuum	From 0.1 to 750 microns	Heated resistor	Temperature sensitive resistor and standardized-voltage source	Pressure	A voltage across a resistance heats it to a temperature which is a function of the gas and pressure surrounding it. The temperature corresponds to a definite resistance.	Resistance	Pirani gauge
17	Vacuum	From 1 to 500 microns	Heated resistor resistor	Fixed resistor and standardized-current source	Pressure	A current through a resistance heats it to a temperature which is a function of the gas and pressure around it.	Temperature	Thermocouple vacuum gauge
18	Vacuum	From 10^{-4} to 1,000 microns (cold), 0–1 micron (hot)	Electronic tube	Electronic tube	Pressure	With a controlled ionizing means, the ion collector current is a function of the pressure for a given gas.	Current	Ionization gauge
19	Vacuum	From 0.001 to 1.0 micron	Moving vane and heater	Moving vane, fixed resistor, and standardized-voltage source	Pressure	The heater creates a level of molecular energy that is higher on the adjacent side of the moving vane than on the opposite side. This difference in energy exerts a torque on the vane which is a function of the pressure.	Torque	Knudsen gauge
20	Fluid flow		Fluid motor	Fluid motor	Fluid speed	A fluid flowing through a fluid motor will move the rotor.	Angular displacement	Gasoline flowmeter

Table II (Continued). Typical Primary Detectors for Measurement of Nonelectrical Quantities

	Quantity Measured	Range of Use	Name	Basic Elements	Input	Physical Effect Output = Kf (Input)	Output	Typical Application
21	Fluid flow		Orifice	Orifice	Fluid speed	A difference in pressure on opposite sides of an orifice exists where fluid flows through.	Differential pressure	Industrial flowmeter
22	Fluid flow		Pitot tube	Pitot tube	Fluid speed	A difference between static and total head is a function of the fluid and its velocity through a pitot tube.	Differential pressure	Aircraft airspeed indicator
23	Fluid flow		Variable orifice	Float and conical tube	Fluid speed	A float in a conical tube will assume a position to vary the orifice size as a function of the fluid speed. The position of the float is therefore a function of the speed.	Linear displacement	Rotameter
24	Liquid level		Float	Float	Liquid level	A light body will be buoyant in a liquid and its position is a function of liquid level.	Mechanical displacement	Float gauge
25	Liquid level		Diaphragm	Diaphragm	Liquid level	A diaphragm is deflected by the head of liquid above and provides a pressure in a closed system which is proportional to the liquid level.	Pressure	Hydrostatic-type liquid level gauge
26	Liquid level	From 0 to 50 ft	Capacitor	Varying dielectric	Liquid level	The capacitance of a capacitor is a function of the dielectric. With two dielectrics such as a liquid and air the capacitance is a function of the dividing line position.	Capacitance	Capacitance gasoline gauge
27	Mechanical displacement		Variable capacitor	Variable capacitor	Mechanical displacement	A change in the relative position of capacitor plates alters the capacitance.	Capacitance	Capacitor-type electric gauge
28	Mechanical displacement	From 0.015 to 30 mils	Variable inductor	Variable inductor	Mechanical displacement	Small changes in air gaps of magnetic cored inductors change their inductance.	Inductance	Electrolimit gauge
29	Mechanical displacement		Voltage divider	Variable resistor	Mechanical displacement	The resistance from a fixed to a variable contact on a resistor changes as a function of the variable contact position.	Resistance	Position telemeter
30	Angular displacement	From 0 to 360 deg	D-c Selsyn transmitter	Variable resistor and d-c source	Angular displacement	A voltage impressed at opposite diameters of a tapped circular resistor sets up a voltage distribution between various taps.	Potential distribution	D-c Selsyn
31	Angular displacement	From 0 to 360 deg	A-c Selsyn transmitter	Electromagnetic stator and rotor and a-c source	Angular displacement	An excited rotor inside a polyphase stator will set up a potential distribution in the stator in accordance with the angular position of the excited rotor.	Potential distribution	A-c Selsyn
32	Angular displacement	From 0 to 360 deg	Second harmonic transmitter	Permanent magnet, saturating coil and a-c source	Angular displacement	Unidirectional flux in a polyphase coil with an a-c saturated core will set up a second harmonic potential distribution dependent on the angular position of the unidirectional flux.	Potential distribution	Second harmonic telemeter system
33	Strain	From 20 to 30,000 microin. per in.	Strain wire	Strain-sensitive resistor	Strain	Strain on wire alters dimensions and resistance of wire.	Resistance	Wire strain gauge
34	Strain	From 0.015 to 30 mils	Strain electromagnet	Variable inductor	Strain	Strain varies air-gap in variable inductor to change its inductance.	Inductance	Electromagnetic strain gauge
35	Weight or force		Spring	Spring	Force	A spring deflects as a function of the applied force.	Mechanical displacement	Spring balance
36	Acceleration	From 0 to 40 g	Spring supported mass	Solid mass and spring	Acceleration	Acceleration moves a mass with a force which is proportional to the acceleration and deflection is controlled by the spring.	Deflection	Aircraft accelerometer
37	Acceleration	From 0 to 10 g	Movable plate and electronic tube	Movable plate, electronic tube and voltage source	Acceleration	In a vacuum tube if the plate is movable, the plate current is a function of the plate position with respect to the cathode. Elastically mounting the plate makes the plate current a function of acceleration.	Current	Vacuum tube acceleration pickup
38	Speed	From 100 to 5,000 rpm	D-c generator	Electromagnetic stator, moving permanent magnet and commutator	Angular velocity	Generated potential is a function of rpm	Direct potential	Magneto tachometer
39	Speed	From 100 to 3,600 rpm	A-c single-phase generator	Electromagnetic stator and moving permanent magnets	Angular velocity	Generated potential is a function of rpm.	Alternating potential	Alternating voltage tachometer system
40	Speed	From 200 to 11,000 rpm	A-c generator	Electromagnetic stator and permanent magnet rotor	Angular velocity	Frequency of generated potential is a function of rpm.	Frequency	Aircraft tachometer or railway type tachometer system

Table II (Continued). Typical Primary Detectors for Measurement of Nonelectrical Quantities

	Quantity Measured	Range of Use	Name	Basic Elements	Input	Physical Effect Output = KF (Input)	Output	Typical Application
41	Speed	From 200 to 5,000 rpm	Magnetic - drag disk	Permanent magnet rotor and eddy-current drag disk	Angular velocity	Rotating magnet reacts with eddy currents in disk to produce a torque which is a function of rpm.	Torque	Automobile tachometer
42	Speed	From 100 to 750 rpm	Fly-ball governor	Movable weights and springs	Angular velocity	Centrifugal force on weights can be balanced against a spring force to give a displacement.	Mechanical displacement	Steam turbine governor
43	Speed		Rotating mirror	Mirror and electric lamp	Angular velocity	Light projected on a rotating mirror is reflected as pulses, the frequency of which is proportional to rpm.	Frequency of light pulses	Electronic tachometer
44	Speed	From 0 to 90,000 flashes per min	Flashing light	Discharge lamp and variable frequency source	Angular velocity	The rate of light flashes is adjusted until the rotating object appears stationary because of stroboscopic effect. When this occurs the frequency of the source is a function of rpm.	Frequency	Electric stroboscope
45	Vibration velocity	From 0.001 to 40 in. per sec	Electromagnetic pickup	Permanent magnet and moving coil	Vibration velocity and frequency	A potential proportional to the velocity is induced in a coil moving in a permanent magnet field.	Potential and frequency	Vibration velocity meter
46	Vibration acceleration	From 10 to 5,000 g	Piezoelectric pick-up	Piezoelectric pickup	Vibration acceleration	A potential proportional to the acceleration appears in a piezoelectric crystal when stressed by vibration forces.	Potential and frequency	Vibration acceleration meter
47	Vibration frequency	From 15 to 500 c	Vibrating reed	Spring and mass	Vibrational frequency	When natural and forced frequencies are equal the amplitude of vibration is maximum.	Mechanical displacement	Vibrating - reed-type vibration meter
48	Sound	From 20 to 120 db	Microphone	Piezoelectric crystal	Sound	Sound energy impinging on a crystal microphone stresses the crystal and the strains produce a voltage as a function of the wave shape of the sound waves.	Potential	Sound level meter
49	Illumination	From 1 to 100 ft-c	Photovoltaic cell	Photovoltaic cell	Illumination	Radiations on a photovoltaic cell results in an emf across the terminals.	Potential	Light meter
50	Illumination	Starlight to 50,000 ft-c	Photoemissive cell	Photoemissive cell Voltage source	Illumination	Radiations on a photoemissive cell result in the emission of electrons.	Current	Phototube light meter
51	Illumination	From 0 to 0.25 ft-c	Photoconductive cell	Photoconductive cell	Illumination	Radiations on a photoconductive cell result in a change in electrical resistance which is a function of the radiation intensity.	Resistance	Infrared meter
52	Illumination		Black body	Black body	Illumination	Light radiations are absorbed and change the temperature of a black body.	Temperature	Thermocouple bolometer
53	Brightness	From 2 to 50 ft-L	Optical wedge	Wedge filter and electric lamp	Brightness	Light of a given brightness will emerge from a wedge filter at a mechanical position dependent on the input light brightness. The position of the wedge in which the emerging brightness agrees with a standard brightness is a function of the input brightness.	Mechanical displacement	Luckiesh - Taylor brightness meter
54	Light energy		Photoemissive cell	Photoemissive cell and d-c source and capacitor	Illumination	Current from a photoemissive cell is a function of the illumination and can be integrated to give light energy for the time interval.	Current	Lumen-second meter
55	Color	400 to 700 millimicrons	Monochromatic lights and photoemissive cell	Electric lamp, prism and photoemissive cell	Transmitted light of various wave lengths	The prism disperses the light to produce the monochronomic lights which are transmitted through or reflect from the color and the resulting light forms a spectrum as a function of the color. It can be compared with a spectrum of a standard.	Spectrum	Recording spectrophotometer
56	Cosmic, X-ray and radiations		Geiger - Muller tube	Geiger-Muller tube and d-c source	Radiations	Radiations, which ionize a gas, will allow electric conduction and certain vapors in the gas will quench the current.	Current	Geiger Muller counters
57	Humidity	From 0 to 95 per cent relative humidity	Wet and dry bulbs	Liquid expansion bulbs and moist wick	Humidity	Evaporation from the moist wic klowers its temperature below that of the dry bulb. The difference between these temperatures depends on the humidity.	Differential temperature and dry temperature	Sling psychrometer
58	Humidity	From 0 to 100 per cent relative humidity	Variable temperature chamber with reflectors	Mirror and heating and cooling source	Humidity	The dewpoint of a gas is detectable by condensation on the mirror surface as the temperature is raised and lowered.	Temperature	Recording dew-point meter
59	Humidity	From 15 to 100 per cent relahumidity	Moisture sensitive resistor	Moisture sensitive resistor	Humidity	Certain salts become moist in humid air and their electrical resistance is a function of humidity.	Resistance	Humidity indicator

Table II (Concluded). Typical Primary Detectors for Measurement of Nonelectrical Quantities

	Quantity Measured	Range of Use	Name	Basic Elements	Input	Physical Effect Output = Kf (Input)	Output	Typical Application
60	Humidity	From 15 to 100 per cent relative humidity	Heated moisture sensitive resistor	Moisture and temperature sensitive resistor and voltage source	Humidity	A voltage applied to a salt such as LiCl which is a conductor only when moist keeps its temperature such that the saturated solution vapor is in equilibrium. The temperature is then a measure of dewpoint.	Temperature	Humidity indicator
61	Humidity	From 0 to 100 per cent relative humidity	Moisture sensitive expandor	Moisture sensitive expandor	Humidity	Some substances change dimensions with humidity changes.	Mechanical displacement	Human hair hygrometer
62	Humidity		Capacitor	Capacitor	Humidity	The capacitance of a capacitor is a function of its dielectric and this varies with moisture content and hence humidity.	Capacitance	Moisture content indicator
63	Viscosity		Constant speed rotor	Vessel and constant speed rotor	Viscosity	The torque on a plunger in a material spinning at constant speed is a measure of viscosity.	Torque	MacMichael viscosimeter
64	Viscosity		Cup and orifice	Vessel and orifice	Viscosity	The time for a given amount of liquid to flow through an orifice is a function of its viscosity.	Time	Saybolt viscosimeter
65	Viscosity		Constant torque rotor	Vessel and constant torque rotor	Viscosity	The speed of a rotor in the material when driven by a constant torque is a measure of viscosity.	Speed	Stormer viscosimeter
66	Viscosity		Falling body	Vessel and ball	Viscosity	An object in a liquid acted on by a known force will accelerate and move through the liquid at a speed which is a function of its viscosity.	Average speed	Falling ball viscosimeter
67	Chemical composition		Diffraction grating	Defraction grating and heat source	Electromagnetic waves	A heated body radiates typical frequencies depending on its composition. A spectrum of these frequencies is formed with a grating.	Spectrum pattern	Spectrograph
68	Chemical composition	Mass range 2 t 400	Mass spectrometer	Electrodes, electromagnets, electron tube, d-c source	Mass as ionized gas	A moving charged mass will follow a given curve if acted on by a field intensity. The curve is a function of the mass.	Mechanical displacement	Mass spectrometer
69	Time	0.1 sec up	Timing motor	Timing motor and a-c standardized frequency source	Time	A constant speed motor will move through a definite angle in a given time.	Angular displacement	Time meter
70	Time	1/4 sec up	Pendulum	Lever, mass, and energy source	Time	A pendulum makes a complete oscillation in a definite time.	Number of oscillations	Pendulum clock
71	Time	0.1 sec up	Balance wheel	Mass, energy storage spring, and energy source	Time	A balance wheel mechanism makes a complete oscillation in a definite time.	Number of oscillations	Stop watch
72	Time	10^{-7} sec up	Crystal oscillator	Crystal and a-c source	Time	A crystal under controlled conditions will oscillate at a constant frequency.	Integrated frequency	Frequency standard
73	Time	10^{-4} sec up	Tuning fork	Tuning fork, electromagnet, and a-c source	Time	A tuning fork vibrates at a constant frequency under controlled conditions.	Number of oscillations	Integrated frequency control instrument
74	Time	0.01 sec up	Vibrating wire	Wire vibrator, electromagnet, and a-c source	Time	A wire under controlled conditions vibrates at a constant frequency	Number of oscillations	Load frequency control
75	Magnetic direction	From 0 to 360 deg.	Compass	Permanent magnet	Magnetic direction	The flux from a horizontal permanent magnet reacts with the horizontal component of the earth's field to produce a torque to turn the magnet into the earth's magnetic field. It will therefore indicate an angle between a given direction and magnetic north.	Angular Displacement	Remote compas
76	Magnetic direction	From 0 to 360 deg.	Second harmonic generator	Polyphase coil, saturable reactor, and a-c source	Magnetic direction	A distributed polyphase winding around an a-c excited saturated core will have a second harmonic potential distribution induced in it as a function of the direction of unidirectional magnetic field cutting it.	Potential distribution	Aircraft automatic pilot directional control
77	Magnetic direction	From 0 to 360 deg.	Induction coil	Rotating induction coil and motor	Magnetic direction	The voltage induced in a rotating coil will be a maximum when moving to cut a maximum of the earth's magnetic field.	Potential	Induction coil compass
78	Space direction	From 0 to 360 deg.	Gyroscope in universal mounting	Gyroscope rotor and energy source	Space direction	A gyroscope acted on by no torques will remain with its spin axis in a fixed direction in space. It will therefore indicate the angle between a given direction and the space direction of the spin axis of the gyroscope.	Angular displacement	Directional gyroscope or bank and climb gyroscope
79	Geographical direction	From 0 to 360 deg.	Gyrocompass	Pendulous gyroscope and energy source	Geographical direction	A pendulous gyroscope with its spin axis horizontal will tend to line its spin axis with the spin axis of the earth.	Angular displacement	Gyrocompass

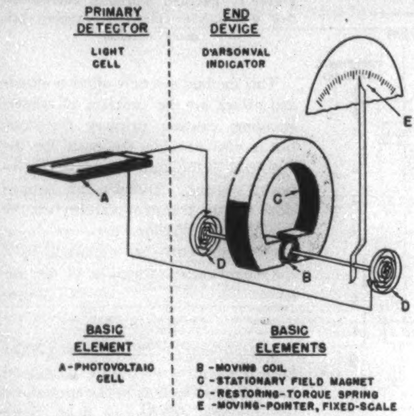

PRIMARY DETECTOR
LIGHT CELL
END DEVICE
D'ARSONVAL INDICATOR
A
B
C
D
D
E
BASIC ELEMENT
A-PHOTOVOLTAIC CELL
BASIC ELEMENTS
B -MOVING COIL
C -STATIONARY FIELD MAGNET
D -RESTORING-TORQUE SPRING
E -MOVING-POINTER, FIXED-SCALE

Figure 4. Light meter

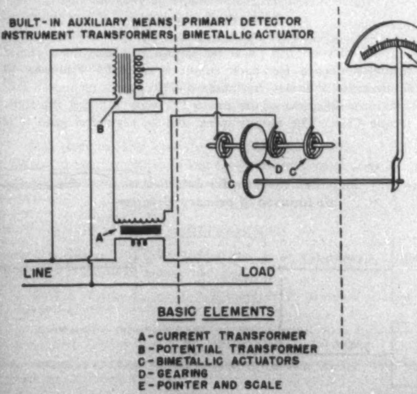
to their inertia) do introduce transients, it is necessary to analyze the transient characteristics and to know how they can be changed.

It should be understood that many quantities such as mechanical deflection, current, and potential are the inputs to primary detectors measuring that quantity, but they also may be the outputs of other primary detectors measuring entirely different quantities. For example, in Figure 4 the light cell has potential as its output. But potential can be the input to a primary detector which might be a permanent-magnet moving-coil mechanism. Mechanisms used as primary detectors in some cases may be used as intermediate means in other cases.

PHYSICAL LAWS AND EFFECTS

Nearly all physical laws have been used in measurement work, and many appear in primary detectors. Some of the important ones are listed in Table III. These laws, together with Newton's laws where mechanical motion is involved and Kirchoff's laws where electric networks are used, make it possible to set up the differential equations for the detector operation.

Figure 5. Thermal watt demand meter


END DEVICE
BUILT-IN AUXILIARY MEANS INSTRUMENT TRANSFORMERS
PRIMARY DETECTOR BIMETALLIC ACTUATOR
E
B
D
C
C
A
LINE
LOAD
BASIC ELEMENTS
A-CURRENT TRANSFORMER
B-POTENTIAL TRANSFORMER
C-BIMETALLIC ACTUATORS
D-GEARING
E-POINTER AND SCALE

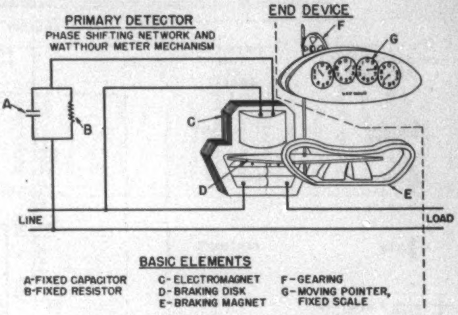

PRIMARY DETECTOR
PHASE SHIFTING NETWORK AND WATTHOUR METER MECHANISM
END DEVICE
F
G
A
B
C
D
E
LINE
LOAD
BASIC ELEMENTS
A-FIXED CAPACITOR
B-FIXED RESISTOR
C-ELECTROMAGNET
D-BRAKING DISK
E-BRAKING MAGNET
F-GEARING
G-MOVING POINTER, FIXED SCALE

Figure 6. Single-phase var-hour meter

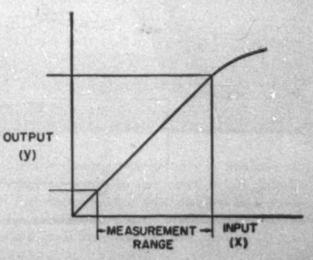
MATHEMATICAL ANALYSIS

In order to obtain an expression for the relation of the output to the input, it is necessary to understand the physical laws and effects entering into the transfer. When these laws are known the determination of the transfer characteristics becomes a mathematical one, techniques for which are covered adequately in mathematical and engineering literature.[4] Standard classical, operational, or transform methods can be used to symbolize the transfer relations. In general, a complete understanding of operation is obtained only after a thorough and sometimes complex mathematical analysis. An adequate understanding is often obtainable, however, from simple qualitative examination of the input, the output, and the physical effect involved.

In general the passive physical elements such as inductance, capacitance, resistance, inertia, and heat capacity, in the interest of simplicity, can be considered constant over the measurement interval. For the same reason, only lumped and not distributed parameters usually are assumed. Mechanical or electrical analogues may be used as well as other artifices commonly applied to the solution of

Figure 7. Input-output characteristic of primary detectors

The output (y) of an ideal primary detector is, over the measurement range, a continuous, determinate, repetitive function of the input (x) only



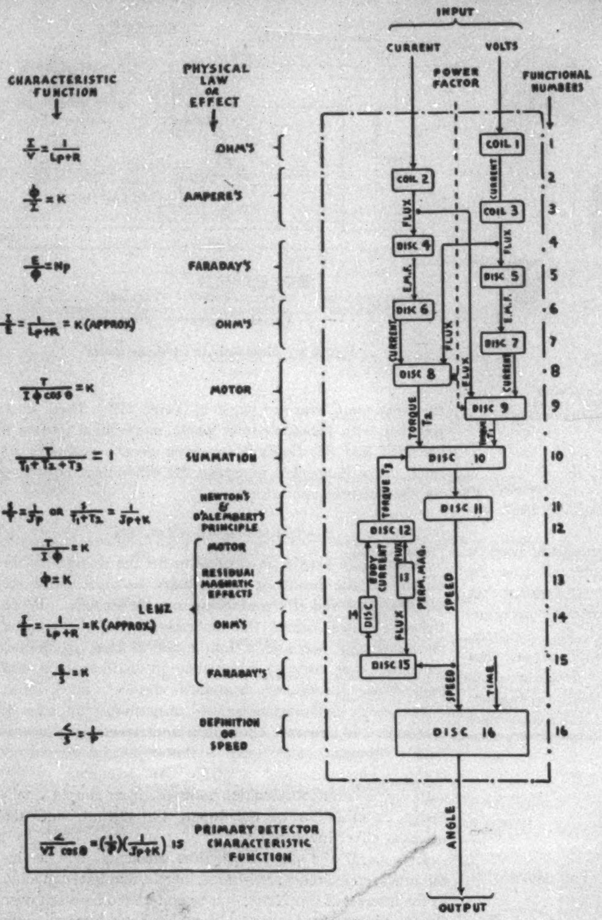

INPUT
CURRENT
VOLTS
POWER FACTOR
FUNCTIONAL NUMBERS
CHARACTERISTIC FUNCTION
PHYSICAL LAW OR EFFECT
$\frac{I}{V} = \frac{1}{Lp+R}$
OHM'S
$\frac{\phi}{I} = K$
AMPERE'S
$\frac{E}{\phi} = Np$
FARADAY'S
$\frac{I}{E} = \frac{1}{Lp+R} = K$ (APPROX)
OHM'S
$\frac{T}{I\phi\cos\theta} = K$
MOTOR
$\frac{T}{T_1+T_2+T_3} = 1$
SUMMATION
$\frac{S}{T} = \frac{1}{Jp}$ OR $\frac{S}{T_1+T_2} = \frac{1}{Jp+K}$
NEWTON'S & D'ALEMBERT'S PRINCIPLE
$\frac{T}{I\phi} = K$
MOTOR
$\phi = K$
RESIDUAL MAGNETIC EFFECTS
LENZ
$\frac{I}{E} = \frac{1}{Lp+R} = K$ (APPROX)
OHM'S
$\frac{E}{S} = K$
FARADAY'S
$\frac{\angle}{S} = \frac{1}{p}$
DEFINITION OF SPEED
COIL 1
COIL 2
COIL 3
DISC 4
DISC 5
DISC 6
DISC 7
DISC 8
DISC 9
DISC 10
DISC 11
DISC 12
13
14 DISC
DISC 15
DISC 16
FLUX
CURRENT
E.M.F.
TORQUE T_2
TORQUE T_1
TORQUE T_3
EDDY CURRENT
PERM. MAG.
SPEED
TIME
ANGLE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
$\frac{\angle}{VI\cos\theta} = \left(\frac{1}{p}\right)\left(\frac{1}{Jp+K}\right)$ IS PRIMARY DETECTOR CHARACTERISTIC FUNCTION
OUTPUT

Figure 8. Detailed functional characteristics of watt-hour meter mechanism primary detector

differential equations. When transform methods are used to express the ratio of the output to the input, this ratio in the primary detector can be called its characteristic function. It can be used to obtain the over-all measuring system characteristic. This is the relation between the end device operation and the quantity being measured. A typical application of this method is the analysis of the watt-hour meter mechanism in the appendix.

This method not only offers a standard attack on the problem of understanding existing primary detectors, but it also provides the basis for the synthesis of the basic elements of proposed systems. Independent expressions for the transient relation and the steady-state relation between input and output can be obtained from the characteristic function of the detector.

CONCLUSIONS

The summary of this work in tabular form is intended for use in the educational field as well as in the specialized measurement engineering field. Since it is intentionally limited to a very general treatment of this phase of measurements, supplementary analysis is necessary for the complete intensive study of any particular system. A method of attack on this problem has been outlined. Finally, there is obvious need for a similar study of the remaining groups in the measurement sequence, namely, the intermediate means and the end devices, for a complete evaluation of this form of measurement analysis.

Appendix

If the detector is subdivided into its basic elements or schematically into functional blocks, a more complete understanding of results is possible. Such a breakdown is shown in Figure 8 for a watt-hour meter mechanism wherein 16 separate detail functions are carried out in three kinds of basic elements involving eight major physical effects.

A little study will show that at function number 8 and 9, torques are produced proportional to the input. Beyond this point the action is similar to a closed loop regulator since a feed-back circuit is utilized. Function 10 acts as an error detector initiating a change in response proportional to the difference of the inputs (T_1 plus T_2) and the feedback torque (T_3). The output speed will be regulated until it is

Figure 9. Simplified diagram for determination of characteristic function of primary detector

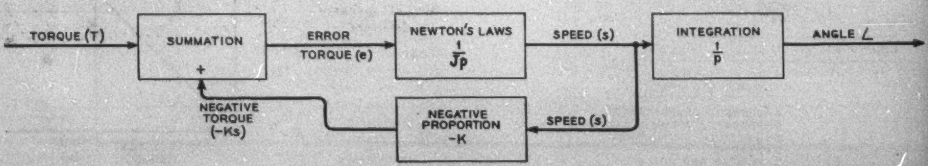

TORQUE (T)
SUMMATION
+
ERROR TORQUE (e)
NEWTON'S LAWS
$\frac{1}{Jp}$
SPEED (s)
INTEGRATION
$\frac{1}{p}$
ANGLE $\angle$
NEGATIVE TORQUE (−Ks)
NEGATIVE PROPORTION −K
SPEED (s)

Table III. Important Physical Laws and Effects Used in Primary Detectors for Measurements

Measured Quantities	Primary Detectors (See Tables I and II)	Laws or Effects*																						
		Ampere's Law	Motor Effect	Ohm's Law	Joule's Law	Seebeck Effect	Coulomb's Law	Edison Effect	Faraday's Law	Expans./Temp	Resist./Temp	Imped./Freq.	Charles' Law	Black Body Radiation	Boyle's Law	Hooke's Law	Res./Dimension	Elastic Limit	Piezoelec. Effect	Archimedes' Principle	Perm. Mag. Phenom.	Capac./Dielect.	Radiation Effect	Photoelec. Effect
Electrical																								
Potential and current	Permanent magnet moving coil	x	x	x																	x			
	Electrodynamic mechanism	x	x	x																				
	Fixed coil moving magnet	x	x	x																	x			
	Thermocouple converter			x	x	x																		
	Electrostatic mechanism			x			x																	
	Electronic rectifier			x				x																
A-c power and demand	Electrodynamic mechanism	x	x	x																				
	D-c watt-hour meter mechanism	x	x	x					x												x			
	A-c watt-hour meter mechanism	x	x	x					x												x			
	Bimetallic actuator			x	x					x														
Frequency	Tuned frequency network											x												
Nonelectrical																								
Temperature	Thermocouple					x																		
	Resistance temperature detector										x													
	Bimetallic actuator									x														
	Bourdon tube												x											
	Filament comparator				x									x										
Pressure	Bourdon tube														x									
	Bellows															x								
	Wire strain gauge															x	x							
	Metal block (hardness)																	x						
	Piezoelectric crystal																		x					
Position and liquid level	Float mechanism																			x	x			
	Capacitor																					x		
	Radioactive source																						x	
Light	Light cell																							x

* Dictionary of Applied Physics, Sir Richard Glazebrook, MacMillan and Company, Ltd., London, England.

proportional to the input T_1+T_2, at which time equilibrium conditions exist.

The simplified diagram in Figure 9 allows the characteristic function of the primary detector to be determined from the characteristic function of the separate blocks. If J is the disk inertia, K is the damping constant, and other terms as defined in the diagram,

$e\left(\frac{1}{Jp}\right)=s$ ....as shown by Newton's laws in the diagram

$(T-Ks)\left(\frac{1}{Jp}\right)=s$ ....since $e=T-Ks$ as shown in the summation

$T-Ks=Jps$ ....by algebraically changing the position of Jp

$T=Jps+Ks=s(Jp+K)$ .by combining the terms with s

$\frac{s}{T}=\frac{1}{Jp+K}$ ....algebraically giving the speed to torque ratio

$\frac{\angle}{T}=\left(\frac{1}{Jp+K}\right)\left(\frac{1}{p}\right)$ ......since the "integration" block shows the angle equals the speed operated on by $1/p$

This demonstrates how the characteristic function $\angle/T$ has been obtained mathematically from the individual characteristic functions of the blocks in the diagram.

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3. Significance of Functional Analysis of Measurements, H. C. Dickinson. *General Electric Review* (Schenectady, N. Y.), October, 1947.

4. Transients in Linear Systems (Volume 1), Gardner, Barnes. John Wiley and Sons, Inc., New York, N. Y.

Steinmetz Memorial Fountain

Gift of the General Electric Company to the city of Schenectady, N. Y., this brilliantly lighted fountain dedicated to the memory of the late Charles P. Steinmetz recently was installed in Crescent Park, not far from the plant where the "mathematical wizard" worked until his death in 1923

Hydroelectric Potentiality of Mexico

ANDRES GARCIA QUINTERO

THE HYDROELECTRIC RESOURCES of Mexico are conditioned by two essential factors, namely, available water and waterfalls. The mean annual surface water runoff of the country's principal rivers is 183,000 million cubic meters brought about by irregular rainfall which occurs for the most part during the summer months. More than 75 per cent of the annual rainfall occurs during these months and this causes the runoff of the rivers to be erratic, making it impossible to take advantage of it to develop power constantly. Reservoirs invariably are reqired to regulate the flow but only 75 per cent to 80 per cent of the total of such stored up water can be utilized as a result of losses occurring through evaporation, spills, and so forth.

Differences in levels of our rivers are greatest on the sides of the eastern and western high mountain ranges which face the sea, where the rivers descend from average altitudes of 2,000 meters to as low as 200 meters to the foothills and coastal plains of the Gulf of Mexico and the Pacific Ocean. These differences occur along river stretches, 200 to 300 kilometers long, forming waterfalls which may be utilized advantageously for hydroelectric development. However the total potential power which these waterfalls could develop cannot be utilized because of losses caused by the location of dams, reservoirs, diversion works, canals and powerhouses, and so forth; and likewise by losses sustained through load friction, bends, and so forth. Thus it is estimated that only 50 per cent of the potential power of Mexico's waterfalls can be utilized.

Table I. Power Installations Constructed in Mexico

Year	Hydroelectric Installations, Kw	Thermoelectric Installations, Kw	Total Kw
1930	262,200	201,400	463,600
1939	389,100	291,300	680,400
1943	397,100	283,000	680,100
1946	463,100	339,800	775,900
1948	511,000		

Mexico has just started to develop her potential hydroelectric resources. Table I shows the power installations made so far. At present the hydroelectric installations have a total capacity of 511,000 kw, with a mean annual demand of 250,000 kw. The estimated total hydroelectric potential is 7,300,000 kw indicating that only 3.4 per cent of the country's hydroelectric resources have been developed.

It should be remembered that Mexico is a country so deficient in water that for an assured agricultural development irrigation is required for 93 per cent of the total area of the country. This leaves only seven per cent of the territory in which natural humidity makes irrigation unnecessary and where it therefore is possible to use all surface waters to generate power. Some idea of the hydroelectric resources of Mexico are indicated in Table II, as gathered by hydrologists in the Ministry of Hydraulic Resources. A comparison of the hydroelectric potentialities of Mexico with that of other nations is indicated in Table III.

Table II. The Hydroelectric Potentialities of Mexico

Hydrographical Regions	Surface Runoff in Millions of Cubic Meters	Horsepower Potentialities	Geographical Distribution in Percentages
Lower California	500	10,621	0.08
North Pacific Region	21,483	4,573,391	34.71
San Pedro-Mezquital	3,150	795,818	6.04
Lerma Santiago Basin	8,680	2,192,457	16.64
Central Pacific Region or Southern Jalisco	5,630	187,477	1.42
Río Balsas Basin	8,650	288,028	2.19
Southern Pacific Region	8,233	222,197	1.69
Río Bravo in Mexico	5,223	227,471	1.73
Northeastern Region (Northern Gulf)	4,390	93,259	0.71
Río Pánuco Basin	6,210	320,878	2.44
Northern region of Veracruz (Central Gulf)	8,230	2,078,961	15.78
Southern Rregion of Veracruz (Papaloapan Basin, Tabasco and Campeche)	95,510	2,062,658	15.65
Enclosed Basins of the Northern Central Plateau	227	1,822	0.01
Central Plateau	1,888	52,024	0.39
Other Regions including Valley of Mexico and Suchiate River	1,440	68,954	0.52
Total	181,294	13,176,016	100.00

Table III. Horsepower Potentials of Several Countries

Country	Horsepower Potential
Africa (Belgian and French Congos)	124,664,879
United States of America	41,689,008
India	26,809,651
China	20,107,239
Canada	17,962,466
Russia	15,951,743
Mexico	9,785,523

It has been estimated that 13,136,729 horsepower could be developed by utilizing available water and waterfalls which then could be used to generate 9,800,000 kw. However, because of the continuous increased use of water for irrigation and other purposes, potentially only 9,785,523 horsepower are available capable of producing 7,300,000 kw. To meet a demand of 7,300,000 kw, installations with a capacity of 19,571,046 horsepower are required, signifying a capital investment of $9,862,000,000.00 (2,000,000,000.00 American dollars).

Digest of paper 48-152, "Hydroelectric Potentiality of Mexico," recommended by the AIEE power generation committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Andres Garcia Quintero is director of hydrology, Ministry of Hydraulic Resources of Mexico, Mexico, Federal District, Mexico.

Editor's Note: A previously published article on a related subject is "Mexico's Electrification Program," by Basil Nikiforoff, Alejandro Paez Urquidi, Alfonso Fernandez Del Busto, and Oscar R. Enriquez, which appeared in *ELECTRICAL ENGINEERING* (*Part I—EE, May '46, pages 193–7; Part II—EE, June '46, pages 245–51*).

A 150-Kw Transmitter for Standard Band Broadcasting

T. J. BOERNER

THE DESIGN OBJECTIVE on a modern 150-kw transmitter, 540 to 1,500 kc per second, was a highly efficient, compact transmitter with fine performance. Ultimate operation and maintenance by personnel of limited technical skill was considered carefully.

High level modulation, successfully applied in the past at lower and higher powers, was chosen as the best system to achieve economical operation with non-critical adjustment for top performance. Choice of high-power electron tubes, four each of the *9C21* type for power amplifier and modulator, and the *857B* for rectifiers, reflects economic considerations as well as availability of standard types Use of the same type tube in the power amplifier and modulator reduces spares requirements and also allows rapid seasoning of spare tubes in the power amplifier before being placed in modulator service. Two high-power 3-phase double-way rectifiers are used, one for power amplifier supply at 11.5 kv the other for modulator supply at 14.0 kv. Analysis of performance requirements versus available rectifier tubes indicated a substantial cost saving through use of two high-power rectifiers rather than a single rectifier at 11.5 kv.

Radio-frequency circuits are single-ended from crystal oscillator through four intermediate amplifier stages and the 150-kw power amplifier. Lagging type pi networks with variable pressurized gas capacitors are used in the output circuits of the two high-power amplifiers to achieve good harmonic attenuation along with ease of tuning and output control.

The audio-frequency system amplifies a plus 10-decibel program signal through a push-pull chain consisting of two high-gain voltage amplifiers, a zero-gain cathode follower driver amplifier (four type *828* tubes), and a final class *B* amplifier using four type *9C21* tubes delivering 90 kw for 100 per cent modulation of the radio-frequency power amplifier.

Stabilized inverse feed back is applied from the modulator output to the input stage to achieve low distortion with an economical tube complement.

Figure 1 shows a scale model of the complete transmitter installed on a single floor. Total floor space back of the front panel is 53 feet 3 inches wide by 21 feet 3 inches deep including right hand and left hand access aisles. The rear equipment including oil-filled transformers and water cooling system can be located under the transmitter in a two floor installation requiring no more floor space. Installation details were worked out so that the complete equipment could be set up in an existing single floor or two floor building by using a standard type of overhead wire duct, standard high-voltage bus work, and standard wall bushings.

Figure 2 shows typical test floor performance at 150-kw carrier output on 640 kc per second. Total power input including all auxiliaries measured 325 kw with no modulation, 358 kw at 25 per cent, and 525 kw at 100 per cent modulation, well within design objectives.

Other performance data and test floor operation proved that all design objectives were met with ample margin to allow for less ideal conditions in the field.

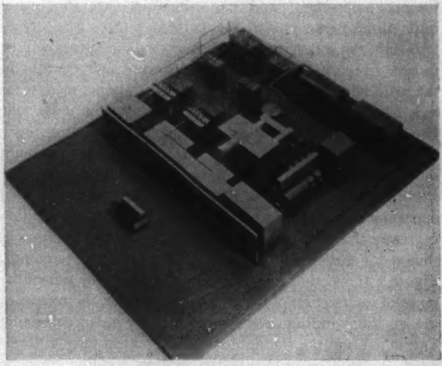

Figure 1. Scale model of a single-floor layout showing access space

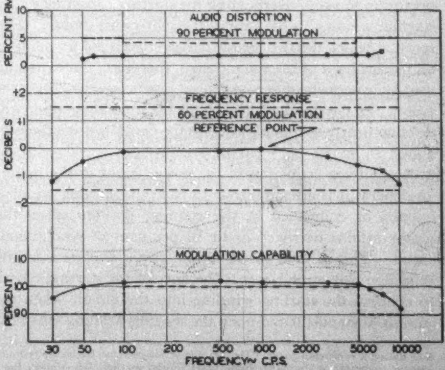

Figure 2. Typical test floor performance, dotted lines indicating specification limits

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Digest of paper 48-132, "A New 150-Kw Transmitter for Standard Band Broadcasting," recommended by the AIEE communication committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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The Starting of Single-Phase Hermetically-Sealed Motors

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The operation of four principal starting devices now in use and a fifth phase-angle eddy-current relay is described. An analysis is given of the characteristics of each device and its effect on the starting characteristics of a single-phase induction motor of the split-phase or capacitor-start type.

A BRIEF discussion of the starting characteristics of split-phase and capacitor-start motors will be necessary to introduce the function and duty of the starting device during the starting period. The curves for the two types of motors (split-phase and capacitor-start) are in general quite similar except for the current curves, and therefore only the capacitor start characteristic curves will be shown. Figure 1 shows curves of torque and current in the main winding versus speed in revolutions per minute for a 1/4-horsepower 4-pole capacitor-start motor under the two conditions of operation of the starting winding, open and closed.[1] The curve of torque *O* (open starting winding) shows that no starting torque will be present unless the starting winding is closed, but that in the range of normal operating speeds the torque developed by the main winding is greater than the torque developed by the combination as shown by the curve torque *C* (closed starting winding). Figure 1 shows that after the speed of the rotor passes the point of intersection of the two torque curves, the torque of the starting winding reverses and become a deaccelerating torque. From the standpoint of the greatest torque developed, it would appear that the starting winding must be connected when the motor is started from rest and continue to be energized up to the speed at which the two torque curves intersect and then be disconnected.

The starting winding must be disconnected during normal operation to avoid overheating the starting capacitor or the starting winding in the case of the split-phase motor. The speed at which the two torque curves cross is not the same in all motors even of the same design, therefore, the switching usually is performed at some speed just below the cross over point. In the standard motor, the main winding alone will develop nearly as much torque as the combined windings at about 75 to 80 per cent of synchronous speed with an accompanying reduction in the power input to the motor. In general it is advantageous to have the starting winding opened or connected in the running position when the motor attains between 70 to 80 per cent of synchronous speed. This gives a speed–torque curve as shown by the solid line in Figure 1. It is the duty of the starting device to connect the starting winding into the circuit when the rotor is at standstill and open the starting winding when the rotor speed passes the maximum torque speed of the motor. A very important condition which must be satisfied is that the relay contacts must not flutter when a capacitor start motor is started because of the danger that the starting capacitor may be damaged. Also, the accelerating torque of the motor will be greatly reduced by a fluttering contact in the starting winding.

The most common type of starting device is the centrifugal type. There is a great variation in the design of the centrifugal switches in use, but essentially their operation is the same. Another type, the so-called current relay, operates on the change in magnitude of the current in the main phase of the motor. A third type is the potential relay, which operates on the voltage variation across the starting winding and is usable only on capacitor start motors. A fourth type is the thermal action relay. A new type of starting device is the phase angle relay. This device operates on the change of power factor of the main winding current as the rotor approaches normal running speed.

The centrifugal-type switch is used on almost all general purpose motors. It usually consists of a set of flying weights counter-balanced by springs adjusted so that at the desired speed the weights move out operating the contacts of the starting winding. It has the advantage of low first cost and a minimum of maintenance expense. The centrifugal device operates the starting switch at the desired point on

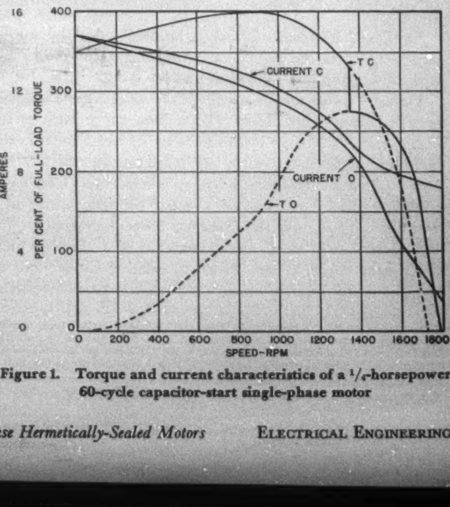

Figure 1. Torque and current characteristics of a $^{1}/_{4}$-horsepower 60-cycle capacitor-start single-phase motor

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Full text of a conference paper, "The Starting of Single-Phase Hermetically-Sealed Motors," presented at the AIEE Great Lakes District meeting, Des Moines, Iowa, April 1–3, 1948.

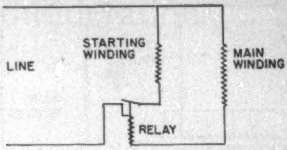
Robert L. Fillmore is an instructor in the department of electrical engineering at the University of Minnesota, Minneapolis, Minn.

the speed torque curve despite poor voltage regulation. However, the centrifugal switch is not well adapted to motors to be used in certain special applications. For example, when a multiple winding motor is used to obtain variations in speed, such as a 2-pole 4-pole 8-pole motor, three different centrifugal switches would be necessary to develop the best starting performance on all windings. If only one switch is used, it may be designed to operate at approximately 75 per cent of the lowest synchronous speed of the motor. When the motor is operated on the higher speed windings, the switch operates to open the starting winding at a low point on the main winding's speed torque curve. In many applications, this low accelerating torque may be insufficient to bring the motor up to normal speed. In an alternate method utilizing a single starting switch, the switch must be designed to operate at about 75 per cent of the highest synchronous speed of the motor. In this instance, the motor must be started on the high speed winding and then switched to the lower speeds. In the latter instance, the starting winding and starting switch are used only in conjunction with the high speed winding.

A large field of motor applications where the centrifugal switch in its simple form cannot be used is in the hermetically sealed compressor motors. These motors are used in connection with refrigerator compressors and are exposed to both oil and refrigerant vapors within the motor shell. The starting circuit must not be interrupted within this motor housing. From experience, a special sealed centrifugal switch for this application has proved unsatisfactory.

It is in the hermetically sealed motor field that the current relays and potential relays have been used to replace the centrifugal-type switch. These relays have the advantage of permitting operation outside of the sealed motor shell, being connected in the leads to the motor or across the leads. The current relay has one coil which is connected in series with the main winding of the motor as shown in Figure 2. A magnetic armature is maintained with the contacts in a normally open position. The contacts are closed by the initial current of the main winding when the motor first is connected to the line. As the rotor speed increases to 75 per cent of synchronous speed, the current in the main winding must decrease at least 15 per cent to operate the magnetic relay armature and open the contacts of the starting switch. The contacts must be closed by the lowest starting current that the motor possibly will experience in service. At the same time, the rotor speed must not increase above the point where the torque curves cross before the contacts are opened, or the performance of the motor will be penalized. This may cause trouble in applications where line voltage variations are in excess of five per cent. On high voltage, the change over from the starting torque curve to the running torque curve takes place at speeds above the speed at which the two torque curves intersect and the motor may have insufficient torque to reach the speeds necessary to operate the relay. When the line voltage is low, the transition from starting to running connection takes place at speeds too far below the speed corresponding to the intersection of the two torque curves and the accelerating torque of the running winding may not be sufficient to carry the motor up to normal speed.

Figure 2. Current relay connection



The potential relay is somewhat more favorable with respect to torque under poor voltage regulation than the current relay. The potential relay consists of a high resistance coil and a magnetic armature which is held in the normally closed position. When the relay is connected as shown in Figure 3*A*, both motor windings are energized by the line switch. As the rotor speed increases, a voltage is induced in the starting winding. The relay is adjusted so that, under normal voltage conditions, the contacts in the starting winding are opened at approximately 75 per cent of synchronous speed. The contacts then are held open by the induced voltage in the starting winding. With the relay connected in this manner, the starting winding will be reconnected when the rotor is stalled by an overload. This restarting cycle will destroy either the motor, the capacitor, or both, unless a protective device is installed in the circuit to open the line. The relay may be connected as shown in Figure 3*B* to eliminate the possibility of the motor restarting when stalled by an overload, until the line switch is opened. The starting winding contacts are held open in this instance by the line voltage across the capacitor and relay in series. The motor still should be protected by an overload device, but the capacitor is not endangered by frequent starts. The starting circuit may be opened at a low speed by the potential relay, but contrary to the current relay this occurs under higher than normal voltage, thus part of the torque that is lost by the early opening of the starting winding is gained by the increased line voltage. In the normal motor design, the effect of below normal line voltage on the action of the potential relay is small until the voltage drop becomes excessive.

The thermal relay is used on a large number of the hermetically sealed motors. It operates on the line current of the motor. The starting contacts normally are closed when the line switch to the motor is switched to the "on" position. The motor then should start. A predetermined amount of time is allowed for the motor to reach normal running speed before the thermal element has heated enough to operate the relay opening the start winding circuit. There are a great variety of circuits using a thermal element to operate the starting switch. It has the advantage of simplicity and low initial cost, but there are also many dis-

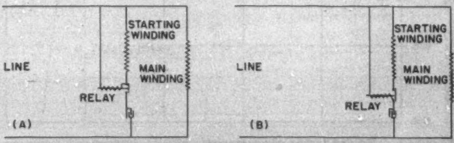


Figure 3. Potential relay connections

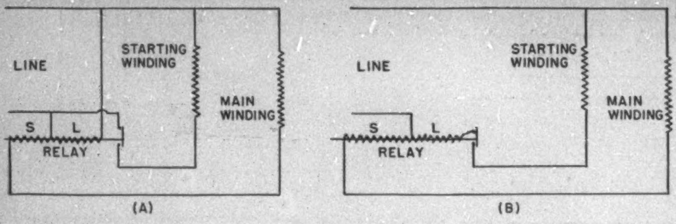


Figure 4. Phase angle relay connections

S—"Series coil"
L—"Line coil"

advantages. One of the disadvantages is that the operation of the switch has almost no connection with the speed torque curve of the motor.

It was in the search for an electrically operated relay to replace the centrifugal switch more effectively that a phase angle relay was investigated at the University of Minnesota, Minneapolis, Minn., by Professor John H. Kuhlmann and the author. This relay operating on the phase shift of the current to the main winding of the motor is applicable to both split-phase and capacitor-start single-phase induction motors. So far as has been determined, the operation of this relay is independent of the applied voltage within the limits usable by the motor. It, like the current and the potential relays, may be mounted outside the motor housing and connected in the circuit as shown in Figure 4*A*. This relay consists of two coils and an eddy current armature. The armature position is such that the contacts are normally open. Closing the line switch starts the main winding current flowing in the "series coil." This closes the contacts to the starting winding and the motor accelerates. When the rotor speed reaches approximately 75 per cent of synchronous speed, the power factor of the main winding passes through unity changing from lagging to leading power factor. This reverses the torque in the armature of the relay and the contacts of the starting winding switch are opened. An alternate method of connecting this relay, usable in some applications, is given in Figure 4*B*. In this instance, the so-called "line coil" of the relay is connected in series with the starting winding of the motor. The contacts are closed by the force of the transformer action between the "series coil" and the eddy current armature. The contacts are opened in this connection when the phase relationship of the currents in the main and starting windings reverse as shown in Figure 5. Figure 5 shows that the current in the starting winding becomes more lagging as the motor speed increases when the large starting capacitor is in the circuit. The current in the main winding changes at the same time from a lagging to a leading power factor. At about 70 to 80 per cent of synchronous speed the two currents are in phase and the starting winding is switched to the running condition by the relay.

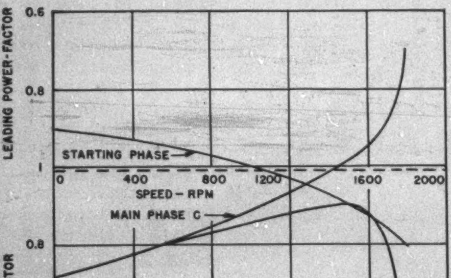


Figure 5. Power factor characteristic of a $^1/_4$-horsepower capacitor-start induction motor

The operation of this relay, like the centrifugal switch, is dependent mainly on the speed of the rotor. It has an advantage over the centrifugal switch, however, in that the speed which operates the phase angle relay is the per cent of synchronous speed, not actual speed. An advantage of the phase relay is that the point of operation of the starting switch varies as the torque curve of each motor varies. The same relay could be used on multiple speed motors and give good performance starting on all speed ranges.

The relay coils can be wound easily for dual voltage motors with no extra connections to the motor.

An outstanding advantage of the phase angle relay is that one relay may be used on a wide range of motors. That is to say, that phase angle relays may be manufactured in mass production for use on motors in size groups, such as one-quarter to one-half horsepower, one-half to one horsepower. In tests at the University of Minnesota the same relay satisfactorily started a $^1/_4$-horsepower split-phase motor and a $^1/_2$-horsepower capacitor-start motor with starting loads varying from zero per cent to 250 per cent full load. The relays need not meet close current specifications. Because of the theoretical condition governing the power factor, a motor with satisfactory torque characteristics will have the required power factor characteristics necessary to operate the relay. In mass production the cost of manufacture of this relay is estimated at less than one dollar.

When rebuilding or repairing motors, it is sometimes very difficult or impossible to obtain the correct or a suitable centrifugal starting switch. The phase angle relay will be a simple and economical solution to this problem in that it may be mounted anywhere on the frame of the motor and connected electrically in the circuit.

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Resistance-Welding Equipment Considerations

C. E. SMITH
MEMBER AIEE

THE METAL FABRICATING industry long has recognized the resistance-welding machine as a desirable metal-joining tool and owing to the tremendous increase in the use of these machines and their processes during the past several years, more engineering information is desirable, not only to the resistance-welding manufacturers, but the electrical utilities and the users of resistance-welding equipment.

Resistance-welding machines have an electrical load of an intermittent nature, high magnitude, and extremely poor load factor making it necessary to provide for adequate electric service. Unless there is an understanding of the present types of correction devices and their effect upon the power supply system is known to all the interested parties, inadequate power supply will result. In some instances, with the large and intermittent demands produced on the supply line, cyclic flickers may be created that become a nuisance to the power server and users of equipment with the result that utility engineers tend to discourage this type of a load or to force some other solution to the problem. The sudden and repeated flow of current to the welder through the impedance of the supply system causes an intermittent voltage drop, which if great enough in magnitude, may cause objectionable flicker of a lamp in the lighting system fed from the same portion of the system.

At the present time, the resistance-welding machines are classified into direct-energy types and indirect-energy types as shown in Figure 1.

Before final application and installation of these various types of welding machines and their correction devices is determined, the effects of the various secondary wave shapes with respect to welding must be known. The advantages and disadvantages of one system versus the other must be known so that application of the particular machine and its correction device is made properly.

Because the installation of resistance-welding machines generally is determined by the permissible regulation of the total power system and not matching of thermal capacity, a discussion of the regulation characteristic of 3-phase and single-phase machines on a 3-phase line is necessary. In Figure 2 various types of correction devices are shown with an assumption of one per cent regulation on the same system (reasonably typical for machines of each type to do the same welding job) and a correction factor of three to one.

The foregoing shows that considerable investigation must be made before determination of the correct type of resistance-welding machine and its correction device is made providing that its secondary wave shape produced this type of system is applicable to the welding specifications.

The final selection of welding equipment must have the following considerations:

1. The ability of the equipment to weld the specified material.
2. The cost of the equipment.
3. The voltage regulation imposed on the supply system by various types of machines.
4. The cost of reinforcement of the present supply system versus the cost of the machines and their correction devices.
5. The total of machines involved and their diversity factor.
6. The rate of production of one system versus another keeping in mind the limitation of each system and the number of machines involved.

The a-c single-phase machine generally is found the most economical if the power supply is adequate, if not, a complete study must be made of the total installation of power system before recommendation of a certain type of machine and its correction device versus power system of reinforcement.

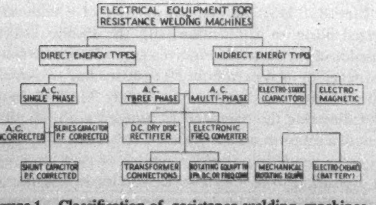
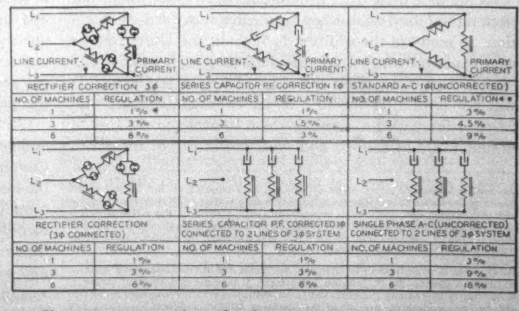

ELECTRICAL EQUIPMENT FOR RESISTANCE WELDING MACHINES
DIRECT ENERGY TYPES
INDIRECT ENERGY TYPES
A.C. SINGLE PHASE
A.C. THREE PHASE
A.C. MULTI-PHASE
ELECTRO-STATIC (CAPACITOR)
ELECTRO-MAGNETIC
A.C. UNCORRECTED
SERIES CAPACITOR P.F. CORRECTED
D.C. DRY DISC RECTIFIER
ELECTRONIC FREQ. CONVERTER
SHUNT CAPACITOR P.F. CORRECTED
TRANSFORMER CONNECTIONS
ROTATING EQUIPT 1Ph. DC, OR FREQ CONV
MECHANICAL ROTATING EQUIPT
ELECTRO-CHEMICAL (BATTERY)

Figure 1. Classification of resistance-welding machines



RECTIFIER CORRECTION 3φ		SERIES CAPACITOR P.F. CORRECTION 1φ		STANDARD A-C 1φ(UNCORRECTED)	
NO. OF MACHINES	REGULATION	NO. OF MACHINES	REGULATION	NO. OF MACHINES	REGULATION**
1	1% *	1	1%	1	3%
3	3%	3	1.5%	3	4.5%
6	6%	6	3%	6	9%

RECTIFIER CORRECTION (3φ CONNECTED)		SERIES CAPACITOR P.F. CORRECTED 1φ CONNECTED TO 2 LINES OF 3φ SYSTEM		SINGLE PHASE A-C(UNCORRECTED) CONNECTED TO 2 LINES OF 3φ SYSTEM	
NO. OF MACHINES	REGULATION	NO. OF MACHINES	REGULATION	NO. OF MACHINES	REGULATION
1	1%	1	1%	1	3%
3	3%	3	3%	3	9%
6	6%	6	6%	6	18%

Figure 2. A comparison of various types of corrective equipment

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Digest of paper **48-180**, "Resistance-Welding Machine and Power Supply," recommended by the AIEE electric welding committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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A System Frequency Change

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After a half century of operation and growth, the Southern California Edison Company is changing the frequency of its system from 50 cycles to 60 cycles per second. Such a change, involving 700,000 customers, requires detailed advance planning and organization, engineering studies of all equipment that is sensitive to changes of frequency, acquisition of stocks of material, and training of personnel. With the assistance of five contractors, the company expects to complete the change on schedule in October 1948 after two years of actual conversion work. In this instance, many items of equipment could be used at the new frequency with only minor or no change, and the system henceforth can operate at the generally accepted United States standard frequency of 60 cycles.

THE scheduled completion on October 26, 1948, of the change in frequency from 50 to 60 cycles of the Southern California Edison Company system and its customers' frequency-sensitive utilization equipment will bring to a close the largest program of its kind ever undertaken in the history of the electrical industry.

The frequency of 50 cycles was established in southern California in the year 1893 when a group of pioneer utility men placed into operation the first 3-phase hydroelectric generating units for commercial use in the United States, and it is believed, in the world. These units, consisting of two 250-kw 2,200-volt generators, were installed for local use near Redlands, Calif., a distance of approximately 75 miles from Los Angeles. This early installation was the beginning of the development of a number of small and isolated systems throughout southern California, all of which developed at 50 cycles, and later merged with, or were acquired by, the Southern California Edison Company.

The decision of this pioneer group to use a frequency of 50 cycles was based upon the economics of generating and transmitting electric energy for lighting and power purposes where the load centers were remote from the source of generation, and long distances of transmission were involved.

At the time these early installations were made, there had been no standard established for the frequency of a-c generation, as many of the utilities throughout the United States were experimenting with frequencies ranging from 25 to 133 cycles, depending upon the class of service rendered. It was not until after the turn of the twentieth century that frequencies tended to standardize at 60 cycles in the United States, while in Europe and most of the rest of the world, frequencies were standardized at 50 cycles.

During these early developments in southern California by the privately owned utilities, a number of municipally owned systems also were established in and around Los Angeles, principally in the cities of Burbank, Glendale, Los Angeles, and Pasadena, all of which developed at 50 cycles. As a result, the major portion of the area in southern California, with the exception of that of the San Diego Gas and Electric Company, the territory served by the California Electric Power Company, and a small portion of the City of Los Angeles served by the Los Angeles Gas and Electric Corporation, developed at 50 cycles.

With the introduction of Hoover Dam power and the acquisition by the Department of Water and Power of the City of Los Angeles of the properties of the Los Angeles Gas and Electric Corporation in 1936, that department changed the frequency of its system to 60 cycles. This also necessitated the cities of Burbank, Glendale, and Pasadena likewise to change, as the department is the generating and transmitting agent for Hoover Dam power to these cities.

Because the conversion of these cities to 60 cycles did not affect materially the operations of the Southern California Edison Company, it was not until the war was well advanced that the company gave consideration to the change of its system to the higher frequency. This consideration was brought about because of the large amount of frequency-sensitive items of equipment installed during the war for which the company's customers were required to pay premium prices for 50-cycle equipment, and it appeared this price situation would continue post-war.

On June 8, 1945, the company's executive committee authorized filing an application with the Public Utilities Commission of the State of California for authority to change the frequency of its system from 50 to 60 cycles. Following a public hearing, the commission, on July 27, 1945, issued its order directing the company to proceed with the establishment of a uniform system-wide a-c frequency of 60 cycles and to cease rendering 50-cycle service at such time as it was in a position to render 60-cycle service in lieu thereof. The order further provided that the company assume, in

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addition to the conversion costs of its own equipment, the reasonable direct costs of adapting customers' appliances and equipment for proper operation at a frequency of 60 cycles.

The cost for the conversion of the company's system and its customers' utilization equipment now is estimated at $35,000,000, of which approximately $33,000,000 is chargeable to operations and the balance to plant.

SCOPE AND SIZE OF CONVERSION PROGRAM

From the beginning in 1893, the company expanded in less than 55 years to become the fifth largest privately owned electric utility in the United States in kilowatt-hours generated. The service area covers approximately 18,000 square miles with a system power demand in excess of one million kilowatts with an annual generation of approximately six billion kilowatt-hours. The system serves directly some 75 incorporated cities and 150 unincorporated communities and outlying rural territories. It also supplies energy for redistribution to four municipalities at 50 cycles and to three privately owned utilities on a wholesale basis at 60 cycles. The territory served includes large areas devoted to farming and fruit growing, much of which is made possible by irrigation. Among the more important industries served are the production and refining of oil, production of motion pictures, fruit packing, the manufacture of cement, rubber tires, chemicals, airplanes, oil well equipment, automobiles, and the production and fabrication of iron and steel. In addition, the company serves two electric railways, the Pacific Electric Railway Company operating a system of interurban electric lines in the vicinity of Los Angeles, and the Los Angeles Transit Lines operating electric streetcar lines and trolley busses serving the City of Los Angeles.

The number of customers as of December 31, 1947 totalled 765,000, of which approximately 700,000 were served from the 50-cycle system now under conversion, and the balance at 60 cycles. The 60-cycle service area is located in the San Joaquin Valley where the company acquired the 60-cycle properties of the Mount Whitney Power and Electric Company in 1920 and since has continued serving this area at this frequency.

The foregoing briefly outlines the development of the Southern California Edison Company into a single integrated system serving a highly developed agricultural and industrial area, and is set forth so that the reader may have some idea as to how and why the company's system developed at 50 cycles, and the magnitude of the work involved in converting its system to the now generally accepted United States standard frequency of 60 cycles.

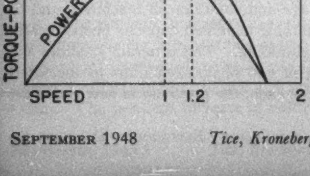

Figure 1. Typical output characteristics of a turbine

Physical conversion began September 6, 1946, and it is estimated that, as of June 1, 1948, the company will have completed the conversion of 525,000 customers, representing 75 per cent of the total, and 1,600,000 horsepower of connected load, representing 78 per cent of the total project.

The conversion is being made concurrently with an unprecedented load growth in the territory served, which requires the planning and construction of new generating and new step-down substations. The 1946–1947 season was one of subnormal precipitation on watersheds of the company's hydroelectric developments and the 1947–1948 season to date is even more deficient in this respect. Operation at two frequencies and outages of steam-electric units for rebuilding tremendously complicate the problem of dry-year operation. Deferred maintenance and repair work that accumulated during war-time operations add their share to the complications of the system conversion. In spite of these complications, however, it is expected that the change from 50 to 60 cycles will be completed on schedule in October 1948.

System Engineering and Operation*

Preliminary engineering of the frequency conversion included investigations of existing equipment and its ability to operate at the higher frequency. The following are fundamental relationships involved in studies of frequency conversion:

1. The frequency of a generator is proportional to the number of poles and to the speed of the rotor.
2. The voltage is proportional to the flux and to the frequency.
3. The reactance ohms are proportional to the frequency.
4. The maximum power input to an inductive circuit with a variable resistance load is proportional to the square of the applied voltage and inversely proportional to the frequency.
5. The centrifugal stresses in rotating parts are proportional to the square of the speed, that is, to the square of the frequency.

PRIME MOVERS

The investigation was begun with a study of prime movers and their performance at variable speed. Nearly all prime movers of generating units on this system are turbines. Typical characteristics of torque versus speed and power output versus speed of a turbine are illustrated in Figure 1. Normal speed and 120 per cent speed are indicated on the curves. It may be noted that at higher than normal speed the power output decreases.

The input to an impulse turbine or water wheel is independent of its speed, hence the reduction of output at higher than normal speed is a loss of efficiency. This loss results from buckets leaving the line of action of the jet before every bit of water completes its work upon the buckets, and therefore some of the water is not utilized. Where this loss is of sufficient magnitude to justify the cost of rebuilding, the wheel diameter is reduced and new buckets of altered design are installed. Some 14 water wheels out of a total of 54 are scheduled for rebuilding.

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* Prepared by H. W. Tice and A. A. Kroneberg.

In the radial-flow type of turbine the water is subjected to centrifugal forces. The centrifugal force opposes the flow of water in an inward-flow turbine so that, as the speed increases under constant head, the discharge tends to decrease. Thus, with a reduction of both input and output, the efficiency of the turbine may change little or not at all. In turbines operating under conditions of low head and large quantity of water, the increase of speed may introduce or intensify cavitation. The company is equipping the three 50-cycle units at Hoover Dam with new runners of smaller diameter and with fillers to fit them into the existing stationary parts; the other 12 turbines on the system require no major changes for operation at 60 cycles.

Steam turbines are subject to additional complications when operated at the higher speed. The elastic limit of materials is reduced at the very high temperatures to which turbine blades are subjected. The increased centrifugal forces at the higher speed may exceed the elastic limit and may cause a permanent elongation of the blades (creep). A steam turbine rotor is a complex structure of disks and blades all having their natural periods of vibration. The rotor is "detuned" for the normal design speed, that is, the disks and blades are designed for natural periods of vibration other than normal speed. The critical speed of the precision-built highly efficient turbines is too near the 120 per cent normal speed to permit safe operation at the latter speed. Of the 11 steam-electric units operating on the system, three are old and relatively inefficient vertical units that cannot be operated at the higher speed, five are 60-cycle units being operated at 50 cycles, and three—the largest and latest of the 50-cycle units installed on the system, with capacities of 60,000, 100,000, and 100,000 kw—are having turbines rebuilt.

There are five diesel-electric units, rated approximately 5,000 kw each, in operation in a leased plant connected to the company lines. The engines were required to be operated as near to their design speed as possible. The generators were rebuilt from 50-cycle 36-pole machines to 60-cycle 42-pole machines. The operating speeds are 166.7 rpm and 171.5 rpm, respectively, an increase of only 3 per cent.

SYNCHRONOUS MACHINES

Currents in windings of synchronous machines (generators, condensers, and motors) have limiting values established by heat produced in the resistance of the windings. These limiting values are held unchanged for operation of the machines at the higher speed. However, maintaining field currents at the same values at either speed means operation at constant flux and the varying of voltage in proportion to the speed. This increase in voltage, if it can be sustained on the existing insulation, is highly desirable from the standpoint of over-all system performance. Ohmic reactances are expressed as percentages or per unit values for use in system-wide studies on a given kilovolt-ampere base. Those values represent the ratio of the IX drop to the rated circuit voltage E. Since X varies with the frequency and I for a given base varies inversely as the voltage E, it is apparent that the per unit value of reactance varies directly as the frequency and inversely as the square of the voltage. Low reactance is the prime factor in the steady state stability of a power system, and is second only to high speed of fault clearing in the transient stability of the system. The maximum increase of voltage on synchronous machines permitted by insulation levels and by available transformer ratio taps is being made at the time of change to 60-cycle operation.

Another important factor in the transient stability of a power system is the inertia constant of a synchronous machine derived from its WR^2 and speed. It may be defined as the time required for the machine to decelerate from full speed to a complete stop with rated torque acting through the entire period of time. With full speed increased to 6/5 of the original speed, WR^2 unchanged, and rated torque reduced to 5/6 of the original torque, the time to come to a stop or the inertia constant is increased to 144 per cent of the 50-cycle value. Further analysis of the inertia constant and its effect on machine performance reveals that it takes 20 per cent longer for a machine to reach a displacement in phase angle of the same number of electrical degrees at 60 cycles than it does at 50 cycles. The effect of increased frequency upon inertia constants of synchronous machines is, therefore, inherently stabilizing and beneficial to the power systems.

The shafts and rotors of synchronous machines are subjected to mechanical stresses and torques. The torques are decreased with increased speed of operation. Centrifugal forces, however, increase as the square of the speed. The rotor structures of rotating machines therefore must be checked for factors of safety used in their design and strengthened or replaced if factors of safety are not deemed to be adequate. Particular attention is paid to stresses in dovetails and in pole tips of salient-pole synchronous machines. Water wheel generators are designed to withstand a runaway speed which is nearly double the normal speed. Operation of water wheel generators at 120 per cent rated speed is therefore feasible and safe. Steam turbogenerators are not expected to be subjected to speeds in excess of 110 per cent normal because of prime mover design limitations. In view of the importance and the size of the three steam-electric units for which turbine parts have been purchased, they also are being equipped with new generator rotors.

Synchronous condensers are required by AIEE Standards to be able to withstand a 25 per cent overspeed. A study of 19 50-cycle machines on the system disclosed factors of safety ranging from 2.5 to 6.0, which are reduced to 70 per cent of their original value when the machines are operated at the 60-cycle speeds. Proper weight was given in the study to the age and condition of machines, and to the possibility of obtaining increased capacity economically through complete rebuilding. The program includes the complete rebuilding of two 30,000-kva units to increased capacity of 45,000 kva each, the purchase of new rotors for five, and the purchase of sets of new poles for rotors of four synchronous condensers and two machines comprising a frequency changer. The 60-cycle machine of this frequency changer required new poles because it was not designed for starting and a starting winding was necessary for operation as a synchronous condenser upon completion of frequency conversion.

The bearing losses in synchronous machines increase as approximately the 3/2 power of speed. In ring oiled bearings, more oil is carried by the rings at higher speed to cool the bearings. Experience of other utilities and that of the company indicates that performance of bearings at the higher speed is unpredicatable, but in general, satisfactory and occasionally even improved over original performance. Direct-connected and motor-driven exciters operating with voltage regulators are expected to give satisfactory performance at 60-cycle speeds. Necessary reinforcing of commutators or notching of pole pieces are details left for determination by tests and detailed engineering.

TRANSFORMERS AND LINES

It is intended to operate power and distribution transformers on the system at the same voltage at 60 cycles as at 50 cycles. The voltages are determined by insulation levels of transformers, busses, transmission and distribution lines, and other equipment. Since voltage is proportional to frequency and to flux, an increase in frequency will result in a reduction of flux and flux density. A reduction in flux in turn means reduced magnetizing current and reduced hysteresis loss. No detectable changes are expected in copper losses and eddy current losses as a result of increased frequency. The reduction in core loss permits an increase of voltage to 107 per cent and a corresponding increase in rated kilovolt-amperes. Similarly, if voltage remains unchanged, the load current may be increased to 103 per cent with a corresponding increase in rated kilovolt-amperes. Tests on representative distribution transformers indicate a reduction of core loss at constant voltage of a little less than one watt per kilovolt-ampere of transformer capacity. Transformer reactance, of course, will be increased to 6/5 of the 50-cycle value and there will be a corresponding increase in regulation.

Characteristics of transmission and distribution lines will be affected adversely by the change of frequency. Reactance and susceptance per mile of line increase with the frequency. Both values enter in transmission line calculations in such a manner that, disregarding effects of conductor resistance, it may be said that a 60-cycle transmission line has approximately the same characteristics as a 50-cycle line 20 per cent longer. Stated differently, it means that the change of frequency is equivalent to increasing the distance of transmission. On short lines of low and medium voltage, it is merely an increase in impedance and regulation. On long high-voltage lines, it also means increased requirements of kilovolt-amperes capacity for charging the line. The per cent increase of charging kilovolt-amperes is more than the per cent increase of frequency, but less than the per cent increase of the square of the frequency, which means a value between 120 and 144 per cent of the 50-cycle value. The per cent increase of voltage rise along an unloaded line also will be considerable. As an illustration, the voltage rise along a Hoover-Chino 220-kv line is 10 per cent at 50 cycles, and is 15 per cent at 60 cycles. The resistance of aluminum-cable steel-reinforced conductors in use on the company's high-voltage transmission lines will be increased approximately 0.7 of one per cent as a result of skin effect.

SYSTEM STABILITY

The term "power system" is applied to the combined interconnection of generators, transformers, transmission lines, and synchronous condensers. The power system combines characteristics of its component parts into characteristics of its own. The more important of these are the steady state and the transient stabilities. Studies were made to determine the extent to which increased voltage of synchronous machines and the corresponding decrease in their per unit reactances were able to offset the increase in transformer and transmission line reactance. The effects of the frequency conversion upon the steady state stability of the company's system are illustrated by the following two summations of reactances of generators, transformers, lines, and remaining system:

50 cycles: $0.60+0.11+0.47+0.26=1.44$
60 cycles: $0.53+0.13+0.56+0.26=1.48$

The ratio of the two summations, 0.97, indicates an approximate loss of 3 per cent in steady state stability resulting from the change of frequency. Studies of transient stability indicate that although transient reactances of the branches of the system show a net increase of approximately 10 per cent, the permissible time of clearing a fault has increased 20 per cent owing to increased inertia constants, the net result being practically the same transient stability within the practical range of fault clearing of 0.2 to 0.5 second.

The preliminary engineering studies outlined in the foregoing paragraphs determined the major items of change in system equipment and were followed by detailed engineering of the changes. This included preparation of specifications, ordering of equipment and parts, investigation and engineering of changes in auxiliaries and accessories, and scheduling the work of conversion.

SYSTEM OPERATION

With equipment to be rebuilt designated by the engineering studies, and the outage times for rebuilding estimated from best available information, it was necessary next to develop a master plan for operation of the system during the conversion of frequency. The conversion, requiring a minimum of two years to carry out, had to be co-ordinated with system expansion called for by the rapidly growing load. Contractual obligations and limitations of interconnections with adjacent utilities introduced additional complications in the planning of operations. The master plan had to be flexible enough to allow for possible delays in obtaining materials without disruption of conversion schedules.

The system may be described as follows: The backbone of the system is a 220-kv 3-circuit transmission line shaped

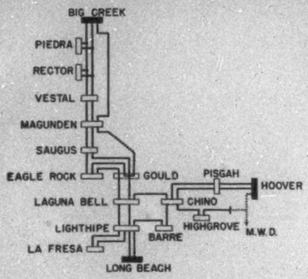

Figure 2. Schematic diagram of the 220-kv backbone of the system

like a right angle L. The bulk of generation is divided into three almost equal groups. One, Big Creek, a group of hydroelectric generators, is located at the top of the L in Fresno county; the second, Hoover, a United States Bureau of Reclamation project on the Colorado River, is connected to the other end of the L; and the third, Long Beach, is a group of steam-electric generators clustered at the apex of the right angle. The distance from Long Beach to either of the hydroelectric groups is approximately 280 miles. Fourteen substations break up the transmission line into 28 sections not counting the line of the Metropolitan Water District of Southern California, which is used jointly by the district and the company. Two of the substations (Pisgah and Gould) are switching stations only; five substations, (Piedra, Rector, Vestal, Magunden, and Highgrove) are stepdown substations supplying 60-cycle power to the San Joaquin Valley load of the company and to interconnections with other utilities; and seven substations, (Saugus, Eagle Rock, Laguna Bell, Lighthipe, La Fresa, Chino, and Barre) are 220–66-kv stepdown substations supplying the main part of the company's load. This part, approximately 90 per cent of the total, is the 50-cycle load being converted to the standard frequency of 60 cycles. Each of these seven major substations is a source of power for one or two subtransmission systems of 66-kv transmission lines and stepdown substations. There is a total of some 90 such stepdown substations involved in the change of frequency, ranging from a simple line tap and a transformer to a switching and stepdown substation with a 10-position double bus arrangement. Transformers at the substations step the voltage down to 16.5 kv or 11 kv for high-voltage distribution, and to 4 kv or 2.4 kv for primary distribution and for customer distribution systems. There are some 110 substations stepping voltage down from high-voltage distribution to 4 kv primary distribution, some 900 substations supplying individual customers, and 90,000 line transformers for supplying 700,000 customers. Approximately 1,100 distribution and primary circuits in the 50-cycle areas are subject to independent switching at a bus and represent the minimum unit for simultaneous switching from 50- to 60-cycle service.

MAIN SYSTEM

In planning the conversion of generating plants to 60 cycles, it was desired to convert each of the three major sources of generation in proportion to the demand of the converted load. This, however, was not entirely feasible because of the large size of some generating units and capacities of transmission lines which made rather large steps of conversion, and because of the long outages for rebuilding which required a staggering of conversion schedules. Some flexibility in the planning of generation during conversion was obtained from the ability of some units to operate satisfactorily at either frequency with a minimum of adjustments. All units at the Big Creek plants can be changed from operation at one frequency to the other in a short time; a 90,000-kw unit at Hoover Dam can be operated at either frequency; an 82,000-kw steam unit at Long Beach is equipped with two governors and can be switched from one frequency to the other without bringing it to a stop. Units at Long Beach totaling 23,000 kw, can be operated at either speed following a shutdown for changes in governor weights. Additional flexibility in the planning of production was provided by two 50,000-kw frequency changers at Chino and Highgrove substations made up of pairs of synchronous condensers coupled together for this service.

It was intended originally to divide the 220-kv backbone into two systems operating side by side, one at 50 cycles and the other at 60 cycles, the two being interconnected through the two frequency changers. The company operates high-voltage interconnections with several adjacent 60-cycle utilities. In the north, near Big Creek, the interconnection is with the two-million-kilowatt system of the Pacific Gas and Electric Company. In the south, the interconnections are with the Metropolitan Water District and Arizona utilities, the Department of Water and Power of the City of Los Angeles, the San Diego Gas and Electric Company, and the California Electric Power Company, all adding up to more than a million kilowatts. Delay in obtaining and installing equipment for tie line control made it necessary to divide the backbone into three, rather than two, separate systems. One of these is the remaining 50-cycle system, the second a 60-cycle system identified with the Pacific Gas and Electric Company, and the third, a 60-cycle system identified with the Metropolitan Water District line.

The arrangement of the subtransmission systems dictated the division of the territory served at 50 cycles into nine conversion areas. The sequence of conversion was determined by the needs of the conversion of customer equipment within limitations of the ability to operate the system in such a sequence.

Figure 2 shows a schematic diagram of the 220-kv backbone of the system. The west line from Big Creek to Magunden and the Metropolitan Water District line from Hoover through Highgrove to Chino were operating at 60 cycles prior to the beginning of conversion. The west Big Creek line was extended to Saugus for the conversion of areas 5 and 6, then to Laguna Bell for conversion of area 8. Area 1, at the same time, was converted to 60 cycles and transferred to Highgrove substation. The conversion of area 2 and of a 100,000-kw unit at Long Beach permitted the linking of all generating sources with a 60-cycle line by switching sections to make one Laguna Bell-Lighthipe-Long Beach line and one Hoover-Pisgah-Chino-Barre-Lighthipe line. After this, the 60-cycle system gradually is increased by transfer of line sections from the 50-cycle system. Load checks were made from time to time in order to keep control of loading of transmission lines and of transformer banks.

SUBTRANSMISSION SYSTEM

It is impossible to review in detail all the line arrangements and switching procedures planned and executed for the conversion of the subtransmission systems to 60 cycles, but some of the methods used in the planning of switching facilities and some exceptional installations deserve description. One of the principles of planning was to progress with conversion along the outside of loops formed by 66-kv transmission lines. Nearly all major substations and eight of the stepdown substations are equipped with double 66-kv busses with each position connected to each bus through an oil circuit breaker. It is a simple matter of assigning one bus to 60-cycle service and the other to 50-cycle service for the period of operation at two frequencies. Twenty of the 90 stepdown substations are simply transformer banks tapped from a line. These substations are usually of low capacity and, with the line, are switched over to 60-cycle service in one operation. Twenty-four substations have single bus or ring bus arrangement of switching facilities. These substations have no more than two line terminals and two banks of transformers to handle, and separation of lines and transformers can be made without temporary connections. An operating bus and a transfer bus arrangement is the prevailing arrangement at the substations of the company, it being used at 38 substations for 66-kv bussing and being the standard arrangement at the lower voltages. When the number of positions on such a bus exceeds five, it is usually necessary to install temporary connections for operation at two frequencies. The preferred practice is to string a temporary "cutover" bus parallel to the operating bus and to connect to this bus through disconnecting switches all circuit breakers except those scheduled for the last day of conversion.

It is not always possible to make installations of temporary busses at a substation, owing to lack of space and obstructions of various kinds. In such cases, a study is made and some other means devised for accomplishing the necessary switching. A cut in the operating bus at some ten locations permitted the operation of the stations at two frequencies. The transfer bus was used as a cutover bus at a number of locations where the time of conversion was of short duration. The diagrams of Figure 3 illustrate temporary connections of a circuit to the temporary cutover bus and temporary connections to the transfer bus when the latter is used for conversion.

Among the problems of line and bus switching, two are believed to deserve attention—the installation of a third 66-kv bus at La Fresa, and the method of conversion of area 2. La Fresa substation is located in a zone subject to insulator contamination from salt-bearing mist from the Pacific Ocean and fumes from oil refineries and synthetic rubber plants. It has been the practice at this substation to clean insulators supporting the 66-kv busses every four months. This requires alternate outages of the two busses, which is feasible when operating at a single frequency. The substation was scheduled for operation at two frequencies during 12 consecutive months and, it being a source station, no bus outages could have been arranged during the year. For this reason, a temporary 66-kv bus was constructed paralleling the length of the north bus and connections were made to it from 14 lines in a manner similar to connections made to cutover busses at other substations.

At Barre substation, one 75,000-kva transformer bank supplies area 2. The 60-cycle source of power for the area was established at Chino substation, some 25 miles distant, and two 66-kv lines were routed into the area by means of temporary connections at crossover points and bypass connections at some substations. Approximately half the load in the area was converted to 60 cycles by progressive switching to these lines. At this point, the remaining 50-cycle load was transferred to Lighthipe substation through similar line changes, thus completely relieving Barre substation. The substation then was switched to 60 cycles with the 220-kv line sections and busses. It was again loaded with its 60-cycle load switched back to it from the Chino lines, and the conversion was completed by progressive switching of converted load from Lighthipe to Barre substation.

The method of conversion of area 2 illustrates the method commonly used in converting substations with one bank in service when sufficient spare capacity is available at adjacent substations, and when sufficient circuit capacity is available between substations to carry the load. When such capacity is not available, it is necessary to install temporary transformer banks to provide the needed capacity and frequency. Temporary transformer bank installations were required at 16 of the 66-kv stepdown substations and at many of the 16.5–4-kv and 11–4-kv substations. The company purchased two 3,000-kva mobile substations with taps suitable for operation at 16.5–4-kv or 11–4-kv substations. These mobile units are currently in service as temporary 60-cycle banks at substations under conversion. They are scheduled to remain at various locations from two to five weeks and to be in transit an average of one week.

System operations for frequency conversion are conducted under the direction of a 3-man committee. This committee plans the operations in accordance with the requirements of the frequency change department and coordinates them with regular system operations. It designs the required temporary connections and programs the switching procedures. The temporary connections are installed by the maintenance and construction crews of the operating department and all the switching is performed under the direction of the system dispatcher.

Conversion of Customers' Equipment*

Immediately following the order of the Public Utilities Commission to proceed with the conversion of the company's system to the higher frequency, a separate frequency change department was organized to handle all phases of the project pertaining to the conversion of customers' equipment.

This department was organized on the basis of contracting the preponderance of the conversion work to local concerns so as to avoid taking onto the company's payroll a large number of employees whose services, of necessity, would be terminated at the conclusion of the project. Accordingly, five major contracts were awarded. The Bechtel Corporation and the Stone and Webster Engineering Corporation were employed to perform the survey, engineering, and conversion of commercial and industrial customers' equipment; the California Electric and Maintenance Company, the survey and adaptation of domestic customers' appliances and equipment; the Fluorescent Maintenance Company, the adaptation of fluorescent and mercury vapor lighting units; and the California Electric Service Stations, the adaptation of electric clocks and timing devices.

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* Prepared by W. N. Johnson, J. D. Enefer, E. E. Tugby, and C. L. Sidway.

The principal functions of the frequency change department are to co-ordinate the activities of the contractors' organizations, and to establish the rules, regulations, and policies covering the manner and extent of changes required to be made in the equipment of its customers. In addition to these functions, the department also handles all customer relation problems, newspaper releases, processing of records, mailing of pamphlets and cutover notices, operation of clock depots for the exchange or cycle-change of clocks, scheduling of the cutover of feeders, review of purchases and subcontracts made by the contractors, review of the engineering determinations and conversion methods employed by the contractors, development of basic engineering changes required to be made in specialized items of equipment, and accounts for the costs of the project. The only physical work of conversion performed by employees of the department is the changing out, relagging, and testing of watt-hour meters installed on the customer's premises, and the testing and adaptation of deep-well turbine pumps.

The number of employees engaged in frequency change work by the contractors and the frequency change department at the peak of operations approximated, 1,777, of whom 651 were employed by the department.

BASIC RULES, REGULATIONS, AND PROCEDURES

In ordering the company to proceed with the conversion of its system to a uniform system-wide frequency of 60 cycles, the Public Utilities Commission required the company to assume, within reason, the direct costs of converting its customers' appliances and equipment for operation at the new frequency, but declared that the adaptation of customers' equipment was a joint undertaking to be assumed by both the company and its customers, and that the company in providing such assistance to its customers must be governed by uniform nondiscriminatory procedures. The commission further required the company to prepare a "frequency change manual" setting forth the policies, procedures, and basic engineering data to be followed in the adaptation of customers' equipment, and to place this manual on file for public inspection in each of the company's district offices. The following are excerpts from the "rules and regulations" as approved by the commission:

> The company, except as otherwise herein provided, has the responsibility for adapting customers' utilization equipment to render it capable of performing essentially the same service when supplied from a 60-cycle system as that previously obtained when supplied from a 50-cycle system.

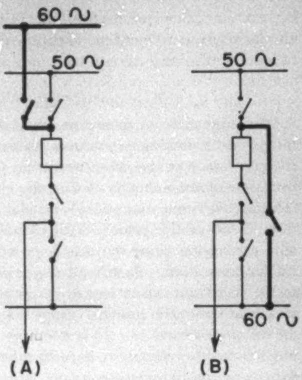


Figure 3. Temporary connection for switching circuits from 50 to 60 cycles

A—From operating to temporary bus
B—From operating to transfer bus

> The company, or its contractors, will make the necessary changes required to adapt the customers' utilization equipment in accordance with the company's engineering determinations. The customer, without charge, will make his utilization equipment available for adaptation and provide necessary assistance to avoid delays during the progress of the work.
>
> The cost of additions, betterments, repairs, or maintenance of customers' utilization equipment is not a part of the reasonable cost of adaptation. Any such work shall be performed at the expense of the customer.
>
> A customer may assume the responsibility of adapting his utilization equipment and in such case the company will make a conversion allowance in lieu of adaptation.
>
> In exceptional cases or unusual circumstances where utilization equipment cannot be adapted for 60-cycle operation at a reasonable cost because of its condition, age, inadequate, obsolete, or nonstandard design, the company will make a conversion allowance in lieu of adaptation.
>
> Rotating equipment will require adaptation only if it is speed critical and in such cases mechanical changes generally will be made in the drive or driven equipment. Where mechanical changes are, in the opinion of the company, not practicable, electrical changes will be performed.
>
> The company's responsibility for the adaptation of the customers' utilization equipment shall cease and terminate 60 days after the date of cutover, except as otherwise provided in this rule and regulation.
>
> In the event any customer's equipment is damaged, as a result of the conversion to a frequency of 60 cycles, the company and its contractors will be liable only if such damage is due to the negligence of the company, or its contractors. Such liability shall be limited to the repair of the damaged equipment.
>
> The company and its contractors shall not be liable for loss or damage, including but without limitation, loss of use, production, or profits resulting from the adaptation of the customers' utilization equipment, or from the conversion of the company's system to a frequency of 60 cycles, except as provided in the paragraph immediately preceding.

PLAN OF CONVERSION

The plan of conversion as originally submitted to the commission under the company's application contemplated that it would require approximately one year for organizing, scheduling, and pre-engineering the work, and $3^1/_2$ years for the physical conversion, with the project scheduled for completion by the middle of 1950. Subsequent studies developed the fact that, because of the unprecedented load growth and increase in population in the territory served by the company, important savings could be effected by shortening the physical conversion to two years. Accordingly, the program was revised to proceed with the conversion in two areas simultaneously, with completion scheduled for October 26, 1948.

As mentioned previously, the system was divided into nine geographical areas, with each served from a major 220-kv substation. A distribution feeder was established as the basic unit for conversion. Studies were made by classification and number of customers, the horsepower of the connected load of each, and the number of deep-well turbine pumps connected to each feeder, and from these data, area cutover schedules were established so as to provide an optimum work load for the several contractors. Detailed feeder cutover schedules then were prepared for each area and referred to the company's operating department for review and determination of the switching and load-carrying requirements, together with the required transmission and distribution line and station switching sequences. The unprecedented load growth experienced by the company since the cessation of hostilities has necessitated careful planning to co-ordinate the frequency change cutover schedules with the company's distribution and transmission system construction program. The many different operations of the several contractors involved in performing frequency change work has made adherence to the feeder cutover schedules imperative once established, changes in these schedules being made only in emergencies, or when it is found that the frequency change program can be expedited by revising the schedules. Present schedules call for the cutover of 1,151 feeders in 378 separate cuts or an average of three feeders per cut. The number of customers' cutover range from one to a maximum of 6,123, with an average of 1,850 per feeder cut. The horsepower of connected load cutover at any one time ranges from approximately 500 to a maximum of 35,310, with an average of 5,430.

BASIC PROCEDURES

One of the most important phases of the program is the establishment and control of the flow of the enormous quantity of paper required to co-ordinate the activities of the various groups involved in effecting the conversion, so that, at the time of cutover of each customer, all of the work necessary for the proper conversion of the customers' equipment to the new frequency has been accomplished. Work flow charts were prepared and used as a base to control all operations of the project. These flow charts show the point of initiation of each item of paper, the action to be taken, the detailed forms to be prepared and processed, the lines of flow for each form, and the final disposition. Early studies indicated the only way in which the records could be handled practicably and economically was by the use of a punch-card and automatic sorting and tabulating machine system. As this was a unique application of tabulating machine operations, the records section had to develop new and unusual methods and procedures. It was determined that the conversion could best be handled by grouping customers into four general classifications, namely, the following:

Class 1—Agricultural power customers having deep-well direct-connected turbine pumps.

Class 2—Industrial customers with a connected load in excess of 50 horsepower.

Class 3—Commercial and small industrial customers with a connected load of less than 50 horsepower.

Class 4—All domestic customers.

Each customer is assigned a frequency change number with 17 digits which identify the customers as to area; the substation source of the feeder from which served; the feeder; the commercial district in which the customer is located; the meter read book; the customer's folio or account number; and the classification of his account. The following illustrates a typical frequency change number:

Area	*Substation*	*Feeder*	*District*	*Meter Book*	*Folio*	*Classification*
4	07	07	31	105	11211	4

The customer's frequency change number controls throughout the entire sequence of operations. For ready reference in handling customers' telephone calls in the area under conversion, an alphabetical list is prepared for each district, showing the customer's name, address, and frequency change number.

Operations are initiated by transcribing to a machine record card data on each customer from the company's district office records, together with the feeder from which the customer is served. From these data, a master record card is punched and the flow of the necessary paper is commenced. It is estimated that during peak operations, approximately 712,000 cards per month will be processed through the records section with a total of 11,200,000 cards for the project.

Customer records are established 12 months in advance of cutover. This allows 4 months for the processing of records and 8 months for the survey and procurement of materials and the scheduling of the cutover with the customer. After these records have been set up in the records system of the frequency change operations, the local district offices, from which the customer records are obtained, are required to keep the frequency change department advised of any change in status of their customers, with the exception of domestic customers. Because of the relatively large number of changes continually occurring in the moving in and out of domestic customers on the company's system, no attempt is made to maintain the initial records of these customers prior to 60 days before cutover. At that time a recheck is made of the district office records of all customers connected to each feeder, and from this date on to the date of cutover, no changes are permitted to be made in the feeder system except under emergency conditions. This lead time of 60 days is maintained so that the mailing pieces outlining the company's program of conversion and the notices of cutover setting forth the date and hour of conversion can be directed to each customer in advance of the changeover, and the contractors' forces scheduled to the customer's premises for the conversion.

PILOT CUTOVER

In order to try out the plan of conversion and to test the procedures developed for surveying and adapting customers' utilization equipment, a small area was isolated from the 50-cycle system and cutover to 60 cycles early in 1946. This involved the cutover of about 4,400 customers with a connected load of 1,008 horsepower. The experience gained from the cutover of this pilot area proved invaluable in developing final conversion plans, procedures, and techniques.

FUNDAMENTAL ENGINEERING PRINCIPLES

Table I shows the connected load of the system together with an estimate of the number of items of equipment to be converted for 60-cycle operation. Included in these items are every type and kind of electrically driven or operated device, ranging from electric clocks to the largest steel mill motor drives. The application of engineering principles to the determination of the changes required to be made for the adaptation of the many thousands of different kinds, types, and makes of frequency-sensitive equipment and devices for operation at a higher frequency is not an exact science. It is a combination of fundamental theories, judgment, and experience. The engineers responsible for determining the adaptation required to reproduce at 60 cycles essentially the same performance which obtained when operating at 50 cycles have no control over the use, or application of the equipment, or of its mechanical or electrical condition at the time of adaptation and, accordingly, must consider many factors, in addition to the theoretical engineering principles involved, in determining the appropriate change. Accordingly, no attempt is made to discuss in detail the engineering theories involved but only to give a general outline of the basic engineering methods and procedures used in effecting the conversion of a few of the more general classes of equipment encountered in a frequency change program of this magnitude.

Table I. Summary of 50-Cycle Customers, Connected Horsepower, and Items of Equipment Requiring Survey, Engineering, and Conversion

	To Be Surveyed and Engineered	To Be Converted
Customers		
Agricultural	7,440	7,440
Industrial	30,426	30,426
Commercial	82,134	82,134
Domestic	580,000	580,000
Total	700,000	700,000
Horsepower		
50-cycle industrial and commercial power load	2,196,800	1,390,800
Per cent "no change"		36.5
Items of customers' equipment		
Total items (all customers)	2,159,800	994,250
Per cent "no change"		53.4
Included in these items are		
Domestic washing machines	369,000	24,600
Domestic refrigerators	332,000	55,400
Electric phonographs	129,000	129,000
Electric clocks and timers	450,000	450,000
Fluorescent and mercury vapor light fixtures	330,000	198,000
Deep-well turbine pumps	7,800	7,250
Company will adapt		4,600
Customer will adapt		2,650
No change	550	
Meters		
Total number replaced, 665,000		
Relagged and tested, 374,500		
New meters installed, 290,500		

The effect of a frequency change on customers' equipment is manifest in various ways for different kinds of equipment, being visible in the case of rotating equipment but generally invisible in the case of nonrotating devices. The most significant and obvious effect on rotating equipment is an increase in speed directly proportional to the increase in frequency. Electrically, a change from 50 to 60 cycles is relatively small and, if it were not for the accompanying speed change, the amount of adaptation required for rotating machines would be materially less. Certain changes occur in the performance characteristics of electric machines affecting magnetizing current, core loss, power factor, efficiency, and torque. In nonrotating devices, the change is apparent only in a change of performance characteristics. It follows that the principal objective in adapting frequency sensitive utilization equipment for operation at a higher frequency is to compensate for the increase in speed in the simplest and most economical manner.

For conversion purposes, frequency-sensitive equipment may be divided into three general classes:

1. Equipment connected to the motor through flexible drives of various kinds and types which can be adapted by a simple mechanical change in the drive to maintain the original speed of the driven equipment. This represents about 54 per cent of the total items of equipment requiring adaptation.
2. Equipment directly connected to the motor, representing about 26 per cent of the total items requiring conversion and consisting principally of centrifugal pumps, deep-well turbine pumps, fans, blowers, and similar devices. Equipment in this class can be adapted in general by mechanical changes to the driven equipment, such as trimming or destaging pump impellers, and trimming or repitching fan blades and blower impellers.
3. Equipment requiring adaptation by an electrical change to the motor or driven unit, or a combination of electrical and mechanical changes. This represents approximately 20 per cent of the total items requiring adaptation.

Approximately one year was spent in engineering research to accumulate pertinent data on common and generally repetitive items of equipment and to establish basic adaptation principles, methods, and procedures for the use of the several contractors. This was necessary in order to provide uniformity of procedure by the several contractors and to avoid duplication of engineering by these contractors. These data were tabulated and set forth in the frequency change manual, and this manual probably contains one of the most complete listing of domestic and commercial electrically-operated equipment extant.

SURVEY AND ENGINEERING PROCEDURES

A field survey is made on forms provided for this purpose of each item of frequency-sensitive equipment on customers' premises, in sufficient detail for the contractors' engineers to determine the appropriate change to be made. The initial survey of commercial and industrial customers' equipment is made approximately eight months in advance of the date of cutover except for certain special items such as large synchronous motors, large air compressors, and heavy mill drives. These items were surveyed as much as two years in advance of the scheduled cutover date so as to provide sufficient time for the procurement of material and parts, which has been one of the most difficult problems.

From the survey data, the contractors' engineers analyze the make, type, and application of each item of equipment and determine the most appropriate and economical change consistent with recognized engineering and machine design standards. Frequently, electrical or mechanical tests are necessary to obtain information for the engineers' use in determining the proper adaptation, to record the 50-cycle performance of the equipment, and to demonstrate that the 60-cycle operation essentially duplicates the 50-cycle operation. Such tests include load and performance tests on motors and generators; hydraulic tests of head, capacity, and efficiency on deep-well turbine pumps and large centrifugal pumps; and mechanical tests of vibration, air delivery, and noise levels. Machines often are found in use in a service for which they were not intended originally by the designer or manufacturer and, in other cases, customers have taken advantage of the increased torque available from a 60-cycle induction motor operating on 50 cycles.

In the large majority of cases, the appropriate change is determined without need of consultation with the manufacturer but, for certain equipment such as large synchronous motors, motor-generator sets, rotary converters, blowers, pumps, and mill drives, it is necessary to obtain data not obtainable by physical survey in order to compute 60-cycle performance characteristics and mechanical stresses. The manufacturers have co-operated generously in supplying information, but in many instances, manufacturers have had no occasion to determine how their appliances or equipment would perform when operated at other than the design speed or frequency and, accordingly, have been unable to furnish all of the desired information without further engineering development on their part.

ELECTRICAL CHANGES

Transformers in general benefit by an increase in frequency. Table II shows the effect of such a change on distribution and power transformers. The efficiency of the transformer usually is improved up to approximately normal full-load because the decrease in iron loss exceeds the increase in copper loss. At overload operation, the efficiency may be slightly less if the increase in copper loss at the higher loads becomes greater than the decrease in iron loss. Constant-voltage-type transformers with tuned circuits or saturation characteristics to control secondary output voltage require modification since the output voltage otherwise would be stabilized at a value considerably higher than the rated voltage. In the smaller sizes, it is generally more economical to replace the transformer. In sizes of 1 kva and larger, modification usually is accomplished by removing the proper amount of core iron and changing the value of the capacitance in the tuned circuit.

Induction and synchronous motors are affected by a change in frequency in the same way as transformers. In addition, the synchronous speed is increased 20 per cent and starting and pull-out torques are reduced. Full load efficiency, in general, will remain the same or will increase slightly. Bearing friction and windage losses increase but these constitute such a small percentage of the total losses that they do not affect the efficiency importantly. Power factor will improve because the magnetizing component of the exciting current decreases considerably. In induction motors, the running torque over the normal range of operation is dependent upon the connected load, and the motor inherently will supply the torque required at the expense of increased slip or a reduction in speed. With the same horsepower output after adaptation, the per cent slip at the 60-cycle speed will remain essentially the same as at 50 cycles. For the average general purpose induction motor, the slip is approximately 3 per cent. If the full load running torque required at 60 cycles is the same as obtained at 50 cycles, the per cent slip will increase to approximately 120 per cent of the 50-cycle value.

The maximum torque varies inversely to some power less than the square of the frequency. Computations and tests indicate that at 60 cycles it will be approximately 73 per cent of the 50-cycle torque. Values less than this obtain on very large motors but generally will approach 69 per cent as a limit, whereas values above 73 per cent in general will obtain on the smaller integral and fractional horsepower motors. Although the maximum torque available decreases, in general application this is of no importance since the very high loads required to reach the point of pull-out practically never occur.

Starting torques decrease approximately as the square of the frequency and, by tests, the 60-cycle value was found to vary between 59 per cent and 65 per cent of the 50-cycle value; the smaller the motor the closer the value approaches 65 per cent. However, as these torques increase as the square of the voltage, they are not reduced below the design torques by the change in frequency to the extent shown because the company's nominal service voltage is 10 per cent higher than the standard design voltages of general purpose motors.

Motors must be modified when it is essential to maintain approximately the same speed as obtained at 50-cycle operation or when it is necessary to maintain the 50-cycle starting and pull-out torques. Speed is maintained by reconnecting, rewinding, or repoling to an increased number of poles. Torque is maintained by rewinding with fewer turns and larger wire. In wound rotor or synchronous motors a rewinding or reconnection of the stator winding also requires a change in the number of rotor poles.

For synchronous motors driving reciprocating loads such as air or ammonia compressors, consideration must be given to the effect on motor current pulsation. Generally, no significant change in pulsation occurs but occasionally, it is found necessary to change the WR^2 of the flywheel. Each case must be studied individually.

The rewinding of a-c machines for an increased number of poles often results in windings with unequal numbers of coils per pole group. Almost all of the practical winding combinations were investigated and catalogued in order that only those resulting in satisfactory motor performance would be used. The major manufacturers have been very

Table II. Per Cent Change in Performance of 50-Cycle Transformers When Operated at 60 Cycles

	Small Transformers, $1^1/_2$ to 25 Kva	Medium Transformers, $37^1/_2$ to 200 Kva
Iron losses	80–90	80–90
Exciting current	40–60	40–60
Total copper loss	101	103
Impedance	109	115
Regulation, 100 per cent power factor	100	108
Regulation, 80 per cent power factor	107	111

co-operative in checking any unusual proposed windings. By the use of such windings, it has been possible to reconnect instead of rewind in many instances, thereby effecting important economies in the cost of motor conversions.

Most motor generator sets are allowed to increase in speed, changes being made to the d-c generators to obtain the proper output characteristics. The parts of a motor generator or rotary converter chiefly affected by increased centrifugal forces are armature bands, wedges, commutators, damper windings, field pole pieces, and pole bobbins. These must be checked carefully to be sure that safe stress limits will not be exceeded. To obtain the data necessary to make the proper modifications and adjustments at the time of speed up, preconversion tests are made, the kind and extent of these tests depending on the size and importance of the unit. In general, additional field resistance is all that is required for the adaptation of generators where regulation or stability is not critical. Machines used in parallel operation or those requiring precise voltage regulation may require a reduction in the cross section of the magnetic circuit in order to restore saturation and maintain stability. This is accomplished usually by slotting the sides of the main pole pieces, the size of the slot being predetermined by calculations based on test data. Some unique techniques have been developed for carrying out this operation, such as flame cutting the slots in pole cores integral with the frame of the generator.

Arc welder motor generator sets constitute a special class. Multiple-operator units use constant potential generators and ballast resistors and are adapted in accordance with standard procedures for general purpose motor generator sets. Single-operator units have differential compound characteristics and are adapted readily for 60-cycle operation by the installation of suitable resistors in the various control fields. Values of resistance to be inserted are selected so as to give the same or a slightly higher open circuit voltage as obtained on 50 cycles.

Industrial control devices depend on electromagnetic forces to activate contactors, relays, and valves. The National Electrical Manufacturers Association rates magnetic contactors in ten sizes from 00 to 8; sizes 00 to 2 and some of size 3 have resistance–reactance ratios such that the loss of pull due to the increased frequency is not sufficient to require correction. The larger sizes are adapted either by the procurement of new coils or by removing 15 per cent of the turns. In critical instances, a tap may be brought out of the coil for 50-cycle operation prior to conversion.

Electric discharge types of lighting such as fluorescent, neon, and mercury vapor, are equipped with current limiting ballasts, containing a reactor or a combination of capacitor and reactor, which are affected by a change in frequency. Those using single reactor ballasts such as neon lights and small single-lamp fluorescents require no modification. In the larger sizes, however, such as the widely used 2-lamp 40-watt high-power-factor type, a change to 60 cycles causes a 10 to 20 per cent reduction in current in the lag lamp with a resulting decrease in light output, and approximately a 70 per cent increase in the lead lamp current with a considerable increase in the light output. This causes injurious heating of the ballasts and importantly reduces the lamp life. New 60-cycle ballasts were unobtainable in the quantities required to meet the conversion schedule, and, as the cost of replacement was high, an adaptor was developed by the department's engineers for use with the existing 50-cycle ballasts to restore the lamp currents to normal 50-cycle values when used on 60 cycles. This adaptor consists of a 3-winding transformer reactor and approximately 50 per cent of the 40-watt 2-lamp fixtures are converted by their use, the remaining 50 per cent being converted by installing 60-cycle ballasts. It is of particular interest that the survey of fixtures to date shows that approximately 40 per cent are equipped with 60-cycle ballasts which have been operating successfully at 50 cycles. Large installations of high intensity mercury vapor lighting were encountered in aircraft plants constructed during the war. Most of these are 2-lamp 400-watt fixtures and are adapted by use of an autotransformer to reduce the voltage across the capacitor together with a tap change on the primary of the ballast transformer.

MECHANICAL CHANGES

The largest class of mechanically adaptable equipment other than flexible driven equipment consists of centrifugal and turbine type pumps. It is estimated that a total of 45,000 pumps of various makes and types will be encountered and adapted during the program. This includes refinery process pumps handling acids, propane, crude oil, caustics, molten salt, light fraction petroleum products, water, and sewage.

Theoretically, a 20 per cent increase in the speed of centrifugal and turbine pumps results in a 20 per cent increase in capacity, a 44 per cent increase in developed head, and a 73 per cent increase in brake horsepower. As has been previously stated, the majority of pumps can be adapted by trimming impellers, if above minimum diameters, or in the case of multiple stage deep-well turbine pumps, by trimming, destaging, or both. Theoretically calculated trims could not be used and it was therefore necessary to develop performance graphs of the various types and makes of pumps based upon empirical values and experience. However, caution must be used in applying these graphs as it is often found upon removal of the impeller that wear has taken place and the amount of trim must be modified accordingly.

In four of the major oil refineries, a total of 2,300 pumps have been engineered for change in this manner. Of this total, only 100 pumps are being replaced because of the impossibility of adapting them to reproduce the same performance on 60 cycles as obtained on 50 cycles.

The problems involved in adapting deep-well turbine pumps are many and complex, being aggravated by changed pumping conditions which have taken place since their initial installation, and in many cases, by receding water tables. The most important factor in engineering the required changes is obtaining accurate test data of the pump's characteristics at 50 cycles. Performance curves when available also are obtained from the manufacturer for each type and size of pump. With these data, it has been possible to determine with reasonable accuracy the change required to reproduce the same head, capacity, and efficiency at 60 cycles as obtained at 50 cycles. In many instances, it has been possible to increase the efficiency of the pump. The poor mechanical condition of many deep-well turbine pumps also has added to the problem of pulling, adapting, and reinstalling them for the higher frequency.

Fans and blowers constitute the second largest group of mechanically adaptable equipment. In general, the same engineering principles are employed in adapting them as those used in adapting pumps. High speed fan or blower impellers frequently require dynamic balancing to insure satisfactory operation at the higher speed after trimming.

Large compressors present a major problem as these units usually are driven by synchronous motors where WR^2 must be taken into consideration. Where it is necessary to maintain the existing compressor capacity, but the compressor otherwise can be speeded up, they often can be adapted mechanically by either installing shorter disk cranks, changing head clearances, installing cylinder liners and smaller pistons, or a combination of two or more of these methods. Where increased compressor capacity is permissible, some large compressors can be adapted simply by the installation of modern valves to replace old style valves.

Many types and kinds of unusual equipment are encountered such as expellors, attrition mills, hammer mills, and electric organs, all requiring special consideration in determining the appropriate adaptation. For example, approximately 200 hammer mills, totalling 10,000 horsepower or an average of 50 horsepower per unit, have been encountered. These usually are driven by 2-pole motors designed for 60-cycle operation but the use of these mills varies widely and, where one mill can go "no change," a similar mill used for a different purpose must be adapted to maintain speed.

Many unusual electrical and mechanical problems have been encountered in the project requiring considerable ingenuity on the part of the engineers, however, space does not permit of detailing these problems and their solutions.

SURVEY AND CONVERSION PROCEDURES

The assignment of customers' equipment to the contractors for survey and conversion is made by classification of the account, namely, domestic, commercial, industrial, and agricultural having direct-connected deep-well turbine pumps. Electric railways are handled separately as a special assignment. The procedure followed in the survey and conversion of each class of customer differs with each contractor, and for this reason will be set forth separately hereinafter.

Each contractor operates as an independent contractor but under the direction of the frequency change department for co-ordination of the work and to assure uniformity of policy. Items of equipment which are common to all customers, such as timing devices and fluorescent lighting, are reassigned to the contractor performing that phase of the conversion. As an example, when the survey men of the domestic contractor find timers, home workshop equipment, small domestic pumps, incubators, and other equipment of a specialty nature on the domestic customers' premises, this equipment is reassigned to the appropriate contractor for engineering and conversion. The domestic contractor is employed to perform the conversion of household appliances only, and is not equipped with the materials or the craftsmen necessary to perform specialty work. This plan of reassignment of specialty items of equipment has been highly satisfactory and has eliminated duplicating stocks of materials and craftsmen having special skills, in each of the contractor's organizations.

The company maintains 26 district offices throughout the territory being cutover to 60 cycles for the conduct of its regular business, and as the frequency change operation progress throughout the areas of conversion, the field organization of the frequency change department and its contractors establish field headquarters in each district. This is done so that a close relationship can be maintained between the district office and the frequency change personnel in all matters concerning customer relations, and the handling of telephone inquiries from the customers. Clock depots also are located in each district for the convenience of customers in cycle changing or exchanging portable clocks. As a result of the continually moving operations, it is necessary to provide office, clock-exchange, and headquarters building space for the frequency change operations of the department and its contractors and, when working more than 25 miles from headquarters, to provide transportation and hotel accommodations for the men.

DOMESTIC CUSTOMER CONVERSION

Frequency-sensitive appliances of approximately 580,000 domestic customers will be cutover during the project. This represents 83 per cent of the total customers involved.

The domestic contractor receives his survey assignments on prepunched and printed tabulating cards showing the name, address, and frequency change number of each customer. On the reverse side of the card, there is printed a list of appliances generally found in the home. These cards are assigned to survey crews who list the items of appliances found on the customer's premises, such as washing machines, refrigerators, and record players, and as they are surveyed, a printed tag is placed on each item of equipment designating whether or not a change is required. At this time, the customer also is advised of the details of the program, the date of cutover, and the approximate time the conversion crews will call at the customer's residence to adapt the frequency-sensitive appliances designated. The survey is made approximately three weeks in advance of the date of cutover and because of the relatively short time to cutover, the survey man (in the course of conversation with the customer) changes the bushings on record players having this type of drive. From the master inventory card prepared by the survey man, a separate conversion card is made out for each appliance requiring change showing the make and model and the materials required for the change. These cards then are assigned to the conversion crews for the adaptation of the appliances, a few days in advance of the date of cutover.

The domestic contractor conducts his field operations from mobile trailer units which are moved into each district as the conversion progresses. Each field unit is self-contained with office trailers for the supervisory personnel, warehouse trailers, and portable shops. All appliances are adapted in the home with the exception of gear-driven washing machines and gear-driven record players which are transported to the portable shops for conversion. He employs approximately 184 men, of whom 66 are on survey and 83 on conversion, the remainder being supervisory and clerical personnel.

The experience to date in the conversion of domestic customers shows that 40 per cent of all customers in this class have frequency-sensitive devices requiring adaptation. The survey of domestic customers currently is being made at the average rate of 28 per survey man day, and conversion at the rate of 8 per man day.

COMMERCIAL CUSTOMER CONVERSION

The 82,134 commercial customers having a connected load of less than 50 horsepower comprise approximately 11.7 per cent of the total number of customers to be cut over, with a connected load of approximately 114,000 horsepower. Included in the commercial classification are restaurants, markets, service stations, small machine shops, doctors, dentists, and other types of small business establishments.

A large majority of the equipment encountered in this class is repetitive and the methods of conversion are set forth in the data book section of the frequency change manual. However, certain equipment, such as walk-in type refrigerating units, medium size compressors, and certain machine shop tools require separate engineering and procurement of materials. Accordingly, all commercial customers are surveyed approximately three months in advance of the date of cutover.

Since a large percentage of the equipment encountered in this group is driven by single-phase motors, special single-phase crews have been organized to make starter spring changes when required. While theoretically, a large portion of the single-phase commercial refrigerating units could go "no change", experience has shown that this equipment is operated with little maintenance and, on speed up, would not transfer from the starting winding to the running winding. As a result, in order to avoid equipment failures and food spoilage, the policy has been adopted of maintaining 50-cycle speed by changing the driven pulley on practically all commercial refrigeration units and changing the setting of the transfer switch on the starting winding of the motors.

Also found in this group are special timing devices such as time stamps, bank check recorders, X-ray timers, diathermy timers, hospital timers, police and fire station timers, and photographic timing equipment, much of which must be converted simultaneously with the feeder cutover. These items are handled by special crews of the clock contractor and are given priority of conversion on the day of cutover. All nonportable clocks are adapted on the customer's premises but the portable clocks are required to be brought into the clock depots for exchange or cycle change, as hereinafter discussed.

INDUSTRIAL CUSTOMER CONVERSION

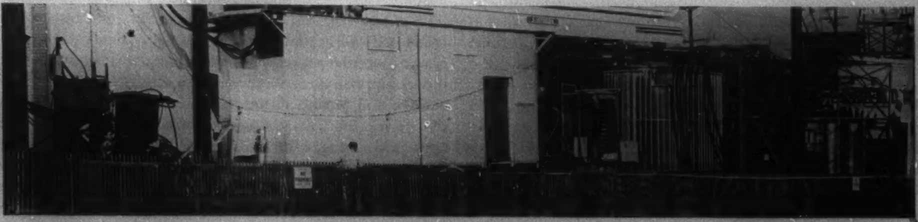
The industrial group having a connected load in excess of 50 horsepower comprises approximately 30,426 customers or 4.3 per cent of the total, with a connected load of 1,619,288 horsepower or 82 per cent of the total connected load to be cut over. The engineering determinations and the procurement of materials require that the survey be made at least eight months in advance of the date of cutover.

Customers in this class are contacted personally by one of the department's commercial divisions employees in company with a representative of the contractor. At this initial contact, the frequency change program is explained and arrangements made for the contractor to survey the equipment. Since in many industrial plants the shutting down of a piece of equipment for survey may interrupt the customer's manufacturing or processing operations, every effort is made to plan and schedule the survey so as to provide the minimum interference with the customer's operations.

Data obtained by the contractor's survey men are processed through the contractor's engineering division and the proper method of adaptation determined. Items of equipment involving costly or unusual changes are referred to

Figure 4. Mobile mercury arc rectifier substation

Showing, from left to right, harmonic filter, rectifier house, heat exchanger, main transformer, transformer cable pothead rack, auxiliary control switches, autotransformers, and oil circuit breakers



the engineers of the frequency change department for review or assistance in determining the propriety of the changes. When the final determination has been made on all items of equipment in a customer's plant, the customer is then advised of the proposed changes and arrangements made for the out-of-service time required for adaptation.

The preponderance of equipment in the average industrial plant can be preconverted with only a few of the more critical items requiring simultaneous change with the cutover of the feeder. Where it is found impossible to take out of service a critical item of equipment, a temporary frequency changer is installed and the conversion postponed for a more favorable time.

While most of the changes in industrial customers' equipment can be performed by reasonably competent electrical or mechanical craftsmen, the contractors found it necessary to train their foremen and field supervisors in the handling of emergencies and unusual conditions which inevitably arise in a program of this size. The field operations of the contractors are carried out from a main field headquarters located in each area and subfield offices located in trailers, each of the latter generally consisting of a warehouse trailer, a small repair shop, and a portable construction house for the clerical and supervisory personnel. Any complaints arising after cutover are handled by trouble crews especially trained for this purpose.

AGRICULTURAL CUSTOMER CONVERSION

Agricultural customers comprise approximately 7,400 customers or 1 per cent of the total, with a connected load of 252,537 horsepower or 12.3 per cent of the total power load to be converted.

Approximately six months in advance of the cutover, a representative of the company calls on each agricultural customer to outline the conversion program and the method of adaptation employed by the company in adapting deep-well turbine pumps. At this time the customer is offered the option of an allowance in lieu of conversion should he prefer to have his own well contractor perform the work or, if he elects, the company will adapt the pump without cost with their own crews. As is shown in Table I, approximately 34 per cent of the customers elect to accept the allowance in the amount of the company's cost so that they can perform repairs or modernize the pump when removed from the well for adaptation. If the customer elects to have the company make the adaptation, the customer is advised that a hydraulic and electric test will be made on the pump so as to establish the 50-cycle pump characteristics necessary for determining the adaptation for the 60-cycle speed. After the tests have been completed and the method of conversion determined, the customer again is contacted, given a summary of the tests, and advised of the proposed method of conversion.

Since the output of a deep-well pump is in part dependent on the draw-down of the water during the pumping cycle and in part on the operating head, which often may be varied by the operation of valves, every effort is made to obtain accurate data at the time of tests as to the standing water level, draw-down during operation, horsepower consumption, output at various heads, and any other data which will assist in making the proper engineering determinations.

The pulling, adaptation, and reinstalling of deep-well turbine pumps is handled by crews trained by the department. These crews are equipped with 20 light-duty and 5 heavy-duty mobile pump-pulling rigs especially constructed in accordance with specifications drawn up by the department's engineering division. The crews operate out of field headquarters, at which mobile machine shops are located, together with the necessary supervisory and clerical staffs. Pump bowls are brought to the portable machine shops for trimming or destaging, and any defective parts are called to the customer's attention in order that he may have them repaired or replaced if he so desires. A large majority of the customers take advantage of this opportunity to put their pumps in good operating condition.

Occasionally pumps are found to be stuck in the well and, after making a reasonable attempt to pull them, the company then offers either to install an offset V-belt drive or to give the customer an allowance in lieu of conversion equivalent to the cost of such an installation. Offset drive heads have been designed by the engineering division and are manufactured locally according to the company's specifications.

At the peak of operations, the pump conversion section of the department had a total of 117 employees engaged in adapting deep-well turbine pumps.

ELECTRIC RAILWAYS

The two railway systems served by the company have connected loads of approximately 151,000 horsepower, mainly in motor generator sets and rotary converters ranging in size from 400 to 1,500 kw. Each of these companies owns and operates its own distribution system which is fed from a number of points of delivery from the power system. The two systems include 63 substations with 77 motor generator sets, 32 rotary converters, and 6 mercury arc rectifiers. Of the motor generator sets, 25 are driven by synchronous motors.

Conversion of the railway units offered a number of problems, not the least of which was the necessity of constructing two mobile d-c substations temporarily to replace the units as they are removed from service for adaptation. One consists of a 1,400-horsepower 2,200-volt synchronous motor directly connected to a 1,000-kw 600-volt d-c generator with associated controls, all mounted on a rubber-tired trailer for outdoor use. A second trailer carries a bank of three 333-kva 16.5–2.3-kv transformers with oil switch and disconnecting switches. The second mobile unit consists of a 6-phase 12-tank mercury arc rectifier rated at 2,400 kw with a control cubicle for 50 and 60 cycles, anode and cathode circuit breakers, and their required controls, all mounted in a weatherproof housing on a rubber-tired trailer. A second trailer carries a 4,500-kva 3-phase to 6-phase 11,500–611-volt transformer and auxiliaries, and a heat exchanger for the rectifier. The rectifier and transformer were obtained from a surplus war plant where one transformer supplied two rectifiers, hence the reason for the oversized transformer. Because the voltage of this transformer does not conform to the voltage of the railway distribution system, a bank of 3-phase autotransformers rated 16.5–11.5-kv is mounted on a third trailer, which also carries the necessary oil circuit breakers and disconnecting switches. This mobile rectifier substation is believed to be the only one of its kind.

Also used in connection with the railway conversion are two sets of load boxes mounted on trailers with variable taps to allow a wide range of current values. Figure 4 shows the portable rectifier substation equipment lined up outside of one of the railway substations.

As the railway distribution systems are served at 17 points of delivery, it was necessary to plan the conversion of the two systems concurrent with the conversion of the company's system at the various feed points. The co-ordination of the conversion of the two railway systems with that of the company's main system, and the transporting, connecting, and disconnecting of the portable substations has required careful planning and scheduling on the part of both the railways and the company.

CONVERSION OF ELECTRIC CLOCKS AND TIMING DEVICES

Since the introduction of electric clocks, a number of the early or small manufacturers discontinued business, which made it impossible to obtain replacement parts and, therefore, the company established an exchange plan whereby the customer has the option of having his clock cycle changed without cost or to exchange his clock for a new and modern one with a small cash payment. Customers are required to bring portable clocks for cycle change or exchange to conveniently located clock depots in the area under conversion.

A majority of the timers used for gas and electric ranges are built in and are adapted on the customer's premises by the clock contractor's field crews. If the range timer is obsolete and parts are not obtainable, the customer is offered a replacement timer.

The use of electric timing devices for the precision control of processes has grown tremendously in the last ten years, and many special applications have been encountered. In most instances, the frequency-sensitive component of these timing devices is a standard clock-type synchronous motor with a rating of 1 or 2 watts and its adaptation for 60-cycle operation consists in general of changing the clock rotor. Arrangements are made with the respective manufacturers to adapt the special and critical timing devices.

The handling of the conversion of clocks and timers is a sizeable project itself and, at the peak of the program 155 men were employed by the department and the clock contractor for this phase of the work.

CONVERSION OF METERS

As all watt-hour meters are frequency sensitive, it is necessary either to replace or adapt approximately 665,000 50-cycle meters on the company's system as well as a number of customer-owned meters. It originally had been planned to retire 275,000 obsolete-type meters during the program. However, difficulty in obtaining delivery of the required number of new meters made it necessary to modify this program, thereby adding importantly to the number of meters to be relagged. A special meter division of the frequency change department was established to handle the replacement or removal, relagging, and reinstallation of all frequency-sensitive meters. Trained meter men in the number required were not available and it was necessary to carry on an intensive training program in order to obtain the required complement of men.

Meter conversion is divided into two major operations, namely, field operations or the replacement of the meters on the customer's premises, and relagging and repair operations which are performed at a central shop on a 2-shift basis. Special meter test tables were designed and constructed for this work.

Information concerning the customer's meter is secured at the same time that the customer's record is picked up in the commercial district office, approximately one year in advance of cutover. This information includes the type, code, year set, mounting, customer's frequency change number, and the name and address of the customer. The information thus obtained is punched in a tabulating card which is used as an order by the meter division for replacing the 50-cycle meter. The meter setter fills in on the card the meter number, code, and reading of the 50-cycle meter before it is removed, and similar information for the 60-cycle meter installed, and the card then is returned to the records section where tabulated lists are prepared and forwarded to the stores and accounting departments and the district commercial offices of the company.

Integrating meters are changed approximately 45 days in advance of cutover, except large power meters which, together with demand meters, are replaced simultaneously with cutover. Field operations are carried out from temporary field offices.

At the peak of operations, 152 men were employed in the meter division.

TRANSPORTATION

The work of converting customers' equipment extends over a service area of approximately 18,000 square miles and the problem of transporting equipment, materials, and employees, and of housing the employees in the more remote areas is one of considerable magnitude. When physical operations were commenced in 1946, automobiles and trucks were difficult to procure. At the peak of operations, there were approximately 344 passenger cars, 388 trucks, 12 office-type trailers, 58 miscellaneous trailers, and 153 personally-owned cars used under operating agreements, or a total of approximately 953 motor vehicles in use by the department and its contractors. This equipment has traveled as much as 771,000 miles in one month.

Table III. Material in Equipment Pool

Quantity	Equipment	Size
53	Frequency changers	1½ to 1,000 kva
2	Gasoline-driven single-phase alternators	10 kw
4	Diesel-driven 3-phase alternators	15 to 20 kw
6	D-c motor generator sets	1 to 1,000 kw
1	D-c rectifier	2,400 kw
2	Portable substations	3,000 kva each
5	Diesel-driven air compressors	315 cu ft per min
5	Water tank trucks	300 to 1,500 gal each

EQUIPMENT AND MATERIAL POOLS

In order to facilitate the adaptation of customers' equipment and at the same time provide equipment for emergency service during conversion, it was found necessary and economically desirable to establish equipment and material pools consisting of special mobile or portable equipment, motors, and pulleys for the use of all contractors under the administration of the frequency change department. The equipment pool contents are listed in Table III. In addition, the pool contains distribution transformers of single and 3-phase types ranging in size from 100 to 1,200 kva. The frequency changers are designed to provide frequencies of 50 and 60 cycles and voltages of 120 to 480 volts. The principal use of the equipment pool is for the preconversion and post-conversion of critical items of equipment in industrial plants, and to provide emergency service at 50 or 60 cycles as required. The two 1,000-kva frequency changers are used primarily for supplying 50- or 60-cycle energy to the two railway systems during the testing and conversion of their substation equipment and to motion-picture studios during the conversion of their motor generator sets.

The motor pool consists of 800 motors of various sizes, speeds, and voltages, ranging in size from fractional and integral horsepower single-phase motors to integral-horsepower 3-phase induction and synchronous motors from 1 to 800 horsepower. These motors are used as replacement motors in the event of emergency or for temporary replacements during the time the customer's motor is out for rewinding or reconnecting.

The pulley pool consists of approximately 20,000 items of various types, sizes, widths, and diameters of pulleys made up of cast iron, split steel, and pressed paper, together with single and multigroove sheaves of various kinds and types. All pulleys and sheaves removed from the customer's equipment are processed through a small machine shop set up in conjunction with the pool stock, and placed in first-class condition for reuse.

CUSTOMER RELATIONS

The maintenance of customer relations in a program of this kind is highly important and involves the co-operation and complete understanding of the objectives by all parties concerned. Where heretofore the company's operations normally stopped at the meter, the operations of cycle changing customers' equipment begin at the meter. This involves many problems never before encountered by the company and required the development of new policies and procedures entirely unrelated to the normal operations.

Recognizing that many situations would arise in adapting customers' equipment which not only involved the technical aspects of converting hundreds of thousands of items of equipment, but also that of entering the homes, offices, business establishments and plants of over 700,000 customers to perform the work, the frequency change department organized to handle all customer relation problems with its own personnel. Approximately 30 days in advance of the cutover of feeders in a district, the department opens a frequency change office, staffed with personnel to receive customer calls and to handle customer relation problems arising in connection with the work. This office remains open 60 days after cutover of the last feeder in the district, for by that time the customer relation problems have diminished to the point where the regular district personnel can handle the few remaining problems, with occasional assistance from the frequency change department.

While the problems encountered in changing the frequency of a system of this magnitude are many and the costs large, the project is being completed on schedule and, it is believed, to the satisfaction of the many customers of the company as evidenced by the many expressions of appreciation received.

The Inspectosphere

The Inspectosphere, a specially marked opal glass globe, has been developed by Sylvania Electric Products Inc., to obtain a quick light distribution appraisal of lens-type bulbs whose light distribution pattern is too wide to measure on an ordinary projection screen. In the tests, the lamp is placed in its socket and covered by the globe (left). When lit, the lamp indicates its light distribution pattern (right) which in this instance, was streaky

Central Utility Versus Local Plant Generation

A. H. FRAMPTON
FELLOW AIEE

ADEQUATE, secure, and economical electric power service is a vital part of our present-day industrial economy. The solution to the problem of selecting this service, in many of the varied forms of industrial and commercial establishment, normally is found in the selection of central utility service, the supply of which generally has been entrusted to central electrical utility companies who enjoy virtual monopolies in their respective territories.

However, further investigation of the problem of power service oftentimes is indicated in those specialized, and usually larger, industries wherein the supply of steam, at various pressures and in substantial quantities, is one of the basic factors of plant design, or wherein plant processes present opportunities for energy recovery that cannot be ignored. Such industries will include, among others, those engaged in the refining of petroleum products, in chemical processes, in paper production, ore reduction or refining. Certain forms of commercial establishment, such as hotels, larger office buildings, and hospitals, may be included in the former category. In these instances, economic and other arguments may be advanced in favor of an independent, local generating plant, co-ordinated with the steam demands of the industry or with its other energy recovery possibilities.

It is the object of this article to present and discuss certain principles inherently involved in the study of such instances, and to indicate that the selection, design, and correlation of the various plant services requires a detailed knowledge of all the factors involved.

Modern industry usually purchases its major apparatus and equipment on the basis of a specification which the apparatus or equipment is required to meet. The preparation of such a specification serves two useful purposes: First, it clarifies the thinking of the purchaser regarding the nature, the limitations, and the expected performance of the item to be purchased; and second, it becomes a statement to the supplier as to the type of product he is expected to offer and to supply.

Electric power service, in the instances under discussion, also is a competitive adjunct of industry, to be supplied by the central electrical utility, or from the independent local generating plant. It naturally follows that a specification, which provides a basis for the comparison of the competing power sources, would be of material assistance in selecting that service most suited to the needs of the enterprise at large. Such a specification might be summarized somewhat as follows:

(*a*). *Dependability*—the power service should be dependable and, in so far as practicable, free from interruptions that hamper plant production and independent of natural forces and other conflicting influences outside the control of the industry.

(*b*). *Quality*—the service should be of such quality as to provide satisfactory voltage, frequency, and other electrical characteristics necessary to the maintenance of established production standards.

(*c*). *Convenience*—the service should be convenient and should not require, without adequate compensations in other directions, the establishment of trained staff, purchasing practices, and other plant procedure foreign to the major objectives of the industry.

(*d*). *Adaptability*—the service should be adaptable to the varying needs of the industry in its cycles of expansion or contraction, and should not create undue delays at the one time nor, at other times, give rise to burdensome charges that must be met during periods of low production.

(*e*). *Economy*—last, but by no means least, the service should be economical, measured in terms of both the direct and the indirect costs, as these may be reflected into the plant production.

Limiting the discussion to those instances where "by-product" power may be generated in noncondensing turbines, and comparing the alternative power sources on the basis of the foregoing specifications, giving due consideration to the joint operation of the local plant with the central utility, some interesting conclusions can be drawn.

In each instance where the comparison of a local plant as against central utility service is undertaken, a new set of conditions will be presented. There is no absolute scale against which any proposal can be checked, the final evaluation depending almost entirely on the ability of the engineer to determine the limiting factors, and on his judgment in presenting them in their correct relationship. Unless the designer is absolutely honest with himself, he may be in the position of having made an entirely wrong decision, one which will remain as a monument to his errors of judgment.

It seems desirable that for any new industrial project there should be a specification for the power supply at least as rigid as those for the major items of equipment. The minimum requirements of such a specification would include those factors already listed and others might be added to cover specialized requirements.

In considering the means by which a power service meeting this specification is to be provided, by-product power generation may prove attractive in those industries requiring large quantities of low- or medium-pressure process steam. The decision concerning the extent to which the savings inherent in this method of operation can be realized should be made only after the most careful investigation, if the apparent gains are not to prove illusory.

Joint operation with the utility company, in many instances, will permit full attainment of these inherent economies, while, at the same time, providing other and substantial advantages, not the least of which will be those intangible values difficult to reflect into a purely monetary comparison.

Digest of paper 48-119, "Central Utility Power Service Versus Local Plant Generation in Industry," recommended by the AIEE industrial power systems and power generation committees and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Pulp and Paper Industry Electrical Developments

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ELECTRICAL DEVELOPMENTS have contributed materially to the efficient operation of pulp and paper mills throughout the United States. This can be appreciated readily when consideration is given to the extensive use of power throughout the industry. In the year 1947, the industry required some 14 billion kilowatt-hours to produce 21 million tons of paper.

To obtain high quantity production it has been necessary to mechanize the industry. Mechanization has been carried to a point where each productive worker utilizes some 15 horsepower in power-driven equipment in producing some 800 pounds of paper per day. This is 2.3 times the national average of 6.5 horsepower per worker.

The paper industry, unlike other industries, generates the major portion of its total power requirements, actually 70 per cent as compared to a national average of only 30 per cent. The extensive use of process steam required in cooking pulp and drying paper together with the development of the modern bleeder-type turbine unit and the high pressure and temperature boiler plants permit developing a large portion of the total energy requirements as a by-product of the process steam.

Power is distributed at generator voltage, usually 2,300 volts, to the various load centers where it either is applied directly to the large motors or where it is transformed to lower voltage for application to the smaller motors. The industry has taken advantage of dry-type transformers suitable for indoor location for this service. In power distribution metal-clad switchgear affords the advantages of factory built and assembled equipment with all component parts properly co-ordinated. Such equipment is available with either air-break or oil-break switches and its use results in minimum operating costs. Control centers for both high- and low-voltage mill motors are being applied extensively in the modern mills. Such equipment has the advantage of factory built and assembled equipment with a co-ordinated design resulting in low operating cost.

In the utilization of electric power full advantage has been taken of the recent developments in both electronic and rotating regulators. Electronic regulators have been developed for use with sectional paper machine drive which provide the extreme sensitivity required for accurate control together with the inherent feature of electronic circuits which results in a maintained accuracy of performance without other than routine maintenance.

The Rototrol, a form of rotating regulator as supplied by one manufacturer, provides an accurate regulating device which has been applied to control numerous functions in the paper mill, materially improving the operating performance.

Drives also have been developed to meet the special requirements of new process equipment. Many of these drives are fully automatic and a minimum amount of supervision is required in their operation. With these drives automatic regulators accurately maintain quality control of production.

In the pulp and paper industry the efficient generation and distribution of electric power together with its effective use have contributed materially to a high-quality low-cost product meeting the demands of an ever expanding market

Figure 1. Two 7,500-kw bleeder turbines (operating at 550 pounds per square inch) in the power plant of a large kraft pulp and paper mill where full use is made of by-product power generation

Figure 2. A 1,500-horsepower 277-rpm synchronous motor built for direct connecting to full-log chipper

Both the electrical design and heavy mechanical construction of the motor contribute to low-cost high-quality chip production

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Digest of paper 48-115, "Electrical Developments in the Pulp and Paper Industry," recommended by the AIEE general industry applications committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Physical and Medical Aspects of Radiation

L. L. GERMAN H. M. ROZENDAAL

Health physics, the new branch of radiology devoted to protection of personnel, is still in the experimental and evaluation stage. However, it already has a remarkable service record which has been achieved through continuous vigilance and careful co-ordination of analysis and control. This is the tenth of a series of articles developed by the AIEE nucleonics committee; the entire series will be published in pamphlet form upon its completion.

FOLLOWING the development of atomic energy through its initial stages into its peacetime applications, one traces also the development of that new branch of radiology now known as health physics. With the inception of the Manhattan Project, it was realized that the radiation hazards associated with the contemplated program would be far greater in number and magnitude than ever before experienced in the field of radiation protection. The radiation injury-free records established by project sites such as the University of Chicago, Chicago, Ill.; Clinton National Laboratory, Oak Ridge, Tenn.; and Hanford Works, Richland, Wash., are an outstanding tribute to all the personnel working on these projects, and especially to the relatively few persons concerned directly with the control of the incident hazards. Without such a record, the success of the Manhattan Project hardly could be regarded so completely successful as history now relates.

In addition to a limited number of physicists engaged in the science of radiation hazard evaluation and control, the health physics groups throughout the project were composed chiefly of technical graduates from many fields other than physics. To some this new science is one of keen interest and a challenge for pursuit beyond the initial crisis of World War II. The development of atomic energy for peacetime use has offered to many an opportunity to meet this challenge. The many laboratories now operating under the control of the Atomic Energy Commission continue to employ hundreds of persons in the field of health physics. As was true in the early part of the Manhattan Project, the number of available people qualified for health physics work remains limited.

UNITS OF MEASUREMENT

As in all fields of science involving measurements, radiology and health physics employ units designed to measure the amount of radiant energy absorbed per unit volume of matter. Basic among these measurements is the roentgen. This unit has been defined as that amount of X or gamma radiation whose associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying a charge of one electrostatic unit of either sign. Because the roentgen is defined only in terms of the absorption of the secondary electron energy produced in air by X and gamma radiation, it early became apparent to plutonium project personnel that equivalent units would have to be devised that would be all inclusive for ionizing radiations. The unit rep (roentgen equivalent physical) was derived and defined as that dose of any ionizing radiation which produces energy absorption of 83 ergs per cubic centimeter of tissue. Further, to include more than the ionizing radiations, the term rem (roentgen equivalent man) was derived and defined as that dose of any radiation which produces a biological effect equivalent to that produced by one roentgen of high-voltage X radiation.

TOLERANCE DOSE

In dealing with any substance that may be toxic to the human body, it is necessary to determine what amounts of the hazard can be tolerated without producing any detrimental effects. The International Committee on X-Ray and Radium Protection, formed in 1928, proposed a tolerance dose for X and gamma rays of 200 milliroentgens per day. In 1936, the American Advisory Committee on X-Ray and Radium Protection adopted a daily exposure limit

Figure 1. Health physics representative making laboratory survey

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L. L. German is a research associate and in charge of health physics at the research laboratory of the General Electric Company, Schenectady, N. Y. H. M. Rozendaal, doctor of medicine, is also a research associate and is in charge of medical problems at the research laboratory of the General Electric Company.

of 100 milliroentgens per day for X and gamma radiation. With some reservation, this limit has been used throughout the project sites and remains in the project literature today. To guarantee personnel exposure within this limit, the policy at the Knolls Atomic Power Laboratory, Schenectady, N. Y., has been to limit all calculated personnel exposures to 50 milliroentgens per day, thereby providing a safety factor necessary for guarantee in any good protection system. Further, the tolerance dose in the field of health physics is not considered as that dose which should be obtained daily, but as the "maximum permissible dose," and usually is referred to using that terminology. Additional maximum permissible exposure limits now in effect at the Knolls project are presented in Table I. With the exception of the alpha tolerance, the limits presented in Table I are in general for total body radiation. Isolated or limited body exposure generally is not taken into consideration in health physics work with the exception of beta irradiation to the hands. In this instance, it is possible to consider a permissible exposure of 200 millirep per day. Here again, the Knolls project maintains a safety factor of two and limits beta exposure to the hands to 100 millirep per day.

KNOLLS ATOMIC POWER LABORATORY HEALTH PHYSICS

The health physics staff of the Knolls Atomic Power Laboratory has developed around a small nucleus previously trained in the field during the war years. The problems of this organization will be similar to those met by the other groups on the plutonium project. The prevention of radiation exposure to a degree where neither acute injury nor delayed damaging effects can be realized is a responsibility that no protection group can exercise without the complete co-operation of each person employed on the project.

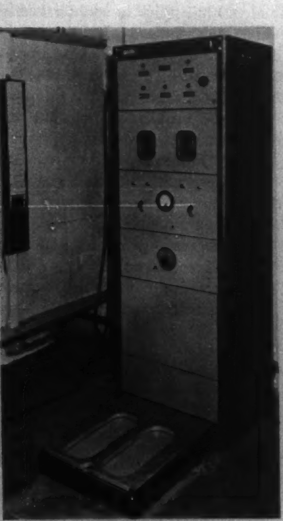

Figure 2. A 5-fold beta-gamma hand and foot counter

To carry out the responsibility of the Knolls Atomic Power Laboratory protection program, the activities of the health physics group have been divided into three main sections. The first of these, known as the survey section, is involved chiefly with the evaluation of the hazards as they are experienced or anticipated in the various programs of the laboratory. This group, with the assistance of many varied instruments, monitors the activities of the research workers following a general review of the problem in which special attention has been given to the possibility of hazardous conditions which might arise during the pursuit of the work. This review period has proved to be a very important part of the protection program, as it acquaints both the research worker and the health physics representative with the potential hazards and the desired control of the same. Because a good protection program is designed to have each worker cognizant at all times of the hazards involved in his work, one of the major roles that the health physics group fulfills is that of conducting a continuous educational program in radiation hazard control.

Detecting and evaluating the radiation hazards encountered in the laboratories is only one phase of this group's activity. In Figure 1, a health physics representative is shown completing a portion of a routine laboratory survey by examining a bench top for alpha contamination. These agents must be aware also of the resultant radioactive waste materials encountered. Because active waste material, both liquid and solid, cannot be discarded for normal disposal, considerable effort is necessary to prevent its fortuitous disposal to city sewers, public waterways, and general public disposal systems. Further, the control of radioactive gases and air-borne particles must be maintained rigidly to prevent their inadvertent travel to other parts of the laboratory buildings or to the outside atmosphere. The responsibility of this health physics section not only includes the project site and its workers, but also must be extended to include the vicinity surrounding the site and its neighboring population. In this connection, complete survey records must be maintained to supplement the legal records of personnel exposure.

The second section, laboratories and control, operates chiefly as a service group to the survey section. Among its many activities is included the preparation of various samples obtained by the survey section for radioactive counting and chemical analysis. The calibration of the survey instruments used throughout the project is carried out by this section, using standard sources emitting the various types of radiation which are to be evaluated in the survey program. The maintenance of these instruments is a most important function and has been effected best by including a group within this section for that specific purpose. Special procedures or instrumentation necessary to complete the survey program often fall as a development responsibility of this section.

As it is desirable to monitor personnel exposure as close to the individual as possible, each person entering the project

Table I. Knolls Atomic Power Laboratory Maximum Permissible Daily Exposure Limits to Radiation

Type of Radiation	Roentgens	Rep	Rem
X ray	0.1	0.1	0.1
Gamma	0.1	0.1	0.1
Beta		0.1	0.1
Fast neutron		0.02	0.1
Thermal neutron		0.02–0.10	0.1
Alpha*		0.1	0.1

* Considered from the standpoint of internal effects only.

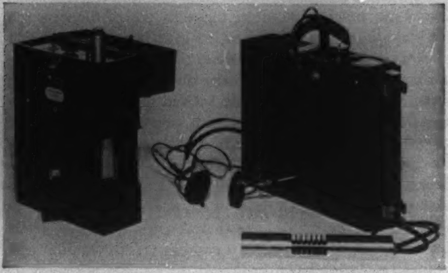

Figure 3. A Lauritsen electroscope (left) and a Victoreen 263A survey meter (right)

site is supplied with a film meter and, in some instances, pocket meters. This distribution has been worked out effectively on the Knolls project by having personnel receive these monitors as they pass through the area gates prior to entering the project site. The preparation and processing of these meters is the primary responsibility of the third group known as the personnel meters section. Personnel exposure records of each person entering the site, whether for work or visitation, are maintained, including the data from these meters. The data obtained in this way constitute the fundamental personnel exposure records and are maintained carefully as part of the legal record of personnel exposure to radiation.

To assist the over-all protection program in the laboratory administered by the General Electric Company's research laboratory, a committee known as the radiation hazards committee was appointed, consisting of members from the various groups of the laboratory. The responsibilities of this committee have been defined

1. To review before publication all project rules and regulations regarding radiation hazard control to insure that such material would be adaptable to each person despite his project activity.
2. To review conditions of unusual incidents arising from violation or inadequate hazard procedures.
3. To foster the protection program through channels of supervision to each individual.

As was learned during the war years, a protection program is controlled more easily in an industrial organization than in an organization involved in research. In the latter type of work, the individual becomes a more important component of the program, therefore much of the health physics group's work deals with individual experimental research.

INSTRUMENTATION

Instruments capable of detecting and measuring alpha, beta, and gamma radiation in addition to neutrons are fundamental tools to the health physicist. Many of the survey instruments developed on the Manhattan Project have proved very reliable and adaptable to the problems confronting the survey personnel. The problem of engineering and developing radiation detecting instruments is an imposing one to any health physics organization. A discussion of instrumentation has been included previously in this series;[1] this aspect is not treated in detail.

Survey Monitors. The Geiger-Müller counter has wide but limited use in the atomic power laboratory. Used for detecting beta and gamma contamination in working areas, on personnel, and on protective clothing worn by persons working with radioactive materials, this type of counter is a useful tool. Despite its adaptability, simplicity and ease of operation, however, this counter has many characteristic disadvantages which limit its use.

The 5-fold beta-gamma hand and foot counter (Figure 2) is one widely used application of the Geiger-Müller tube. Designed for counting the palms and backs of both hands simultaneously with the soles of both shoes, this counter is an important tool to the monitoring program.

Figure 3 shows another application of the Geiger-Müller tube in the Victoreen *263A* meter. In this same illustration, a second portable survey instrument, the Lauritsen electroscope, is shown.

Portable electroscopes serve a number of purposes in which it is necessary to have more precise measurements of the alpha, beta, and gamma activity encountered in the laboratory. Electronic equipment, including ionization chambers and proportional counters, supplements the survey apparatus used as both portable and fixed monitors. Three of the more common electronic instruments in use on the Knolls project are shown in Figures 4 and 5.

Personnel Monitors. The personnel meters, previously mentioned, include a film meter which contains two gamma sensitive films in one dental-size film packet. One of these films has a range from approximately 30 to 3,000 milliroentgens, and the other from 500 to 30,000 milliroentgens. The film meter, complete with a photographic likeness of the person to whom it is assigned, is so constructed that a silver shield approximately 40 mils thick surrounds the film unit with the exception of a small window. Densities of the exposed and developed film are determined by means of a densitometer. The measurements determined on the shielded portion of the film represent X- and gamma ray exposure, while the measurement on the unshielded portion (that part behind the window of the shield) is used to determine soft X-ray and beta exposure. Films prepared by standard radiation exposures are developed with the personnel films and used to evaluate the densitometer measurements as to the roentgens of exposure on the personnel films.

In some phases of the laboratory program, radiation exposure to the worker's hands is more probable than over-all body exposure. To measure and control this hazard, finger film meters are supplied to the individual workers

Table II. Skin Effects From X Radiation

Dose in Roentgens, One Treatment	Skin Reaction	Latent Reaction, Days	Duration, Weeks
200–600	Epilation	21	1–3
700–1,300	Erythema	14	3–4
1,300–1,900	Epidermitis sicca	7	6–12
2,000–2,500	Epidermitis exudativa	2.8	
3,000	Skin necrosis		

These meters are made in the form of rings in which small disks of the previously described film are placed under silver shields provided with a small circular window.

Personnel entering process exclusion areas are provided daily with pocket meters in addition to a film meter. Until performance test data are obtained on the type of pocket meter in use, pocket meters will be worn in pairs to substantiate the indicated exposures. These pocket meters, which are small air capacitors having solid bakelite walls, are charged to approximately 150 volts on a minometer (string electrometer) prior to use and reread on the same minometer following their use. The amount of discharge represents the exposure to X or gamma rays, and provides a daily record of personnel exposure. The limits presently applied to these meters are 5 to 240 milliroentgens gamma radiation. Figure 6 shows a health physics technician processing a pocket meter on a Victoreen projection minometer. Other personnel meters are shown in Figure 7.

There are also in use for personnel monitoring small single fiber electrometers which can be read at any time by the wearer. These meters are provided personnel working in high level fields of radiation as a complementary safeguard to the constant monitoring facilities normally provided by a health physics representative.

EFFECTS OF IONIZING RADIATIONS UPON TISSUES

In order to understand more completely the possible effects of radiation upon animal tissue, it is necessary to review briefly some of the events which may be held responsible for the production of tissue injury.

It is generally accepted that the primary effect of radiation upon tissue is the result of ionization. The ionization, of course, may be produced in a number of ways, somewhat dependent upon the type of radiation used. In general it can be said that the fundamental effects of X rays and gamma rays are alike and consist of electrons projected by photoelectric or Compton effect with subsequent secondary ionization along the electron track. Neutron radiation effects will depend partially upon the number of protons set into motion ($_7N^{14}$, *np*, $_6C^{14}$), with subsequent ionization along the proton track, and a similar primary effect will be observed following radiation of tissue with alpha particles.

It is of interest to consider the number of ionizing events which will take place following the administration of a given amount of radiation. With the doses which it is practicable to give with X rays, the percentage of the reactants which undergoes direct chemical change is usually small and most radio chemical reactions in dilute solutions, such as body constituents, are indirect chemical changes in the solute occurring as the result of ionization and excitation in the solvent molecules.

The number of ionizations produced in a cubic micron of tissue by a dose of 5×10^5 roentgens is about 10^6, and judging from the results of chemical experiments, the number of molecules reacting will be of this order. The number of atoms in one cubic micron, however, is about 10^{11}. Thus even the very large dose of 5×10^5 roentgens produces a rather small direct change, and a dose of, for instance, 50 roentgens would seem quite negligible from this point of view. Yet, marked biological effects in different tissues may be produced with this amount of radiation. To explain why marked biological effects are produced by doses of radiation which produce only a small degree of ionization, the following possibilities must be considered.

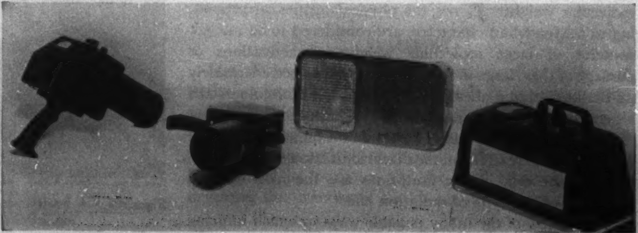

Figure 4. A cutiepie meter (left) and a zeus survey meter (right)

Indirect Action in Aqueous Solution. Experimentally it has been found that the weight of the solute reacting as a result of a given number of roentgens given to the solution is, over a wide range of concentrations, independent of the concentration of the solution.

Similarly, it has been shown by W. M. Dale that to produce comparable percentage inactivations in enzyme solutions of different concentrations, much smaller doses of X rays suffice for the more dilute solutions than for the less dilute solutions. The dose required to inactivate a given weight of the enzyme is, however, approximately the same in different solutions.

These results strongly suggest that the energy dissipated in the solvent is handed eventually over to the solute. Evidently the ionization of a water molecule causes the production of an intermediary body capable of causing reactions in many solutes. These findings explain how dilute solutions of enzymes may be largely inactivated by doses of a few thousand roentgens, which would have practically no effect upon a concentrated solution or a dry preparation. Enzymes are present in cells in low concentration and as their destruction would produce marked effects, it is natural to suspect that enzyme destruction is of importance.

Activated Water Reactions. Because most biological tissues contain large amounts of water and even may be considered as dilute solutions of proteins and other organic and inorganic materials, the changes which take place in water or in dilute solutions following radiation should be considered carefully.

The ionization of the water molecule will result in the ejection of an electron with splitting of the molecule into a hydrogen ion and a hydroxyl radical: $H_2O \rightarrow H^+ + OH^-$. In addition, the production of H_2 and O_2 gases will lead to formation of some H_2O_2.

The oxidation of inorganic ions by OH radicals or their reduction by H radicals explain most of the reactions which have been observed.

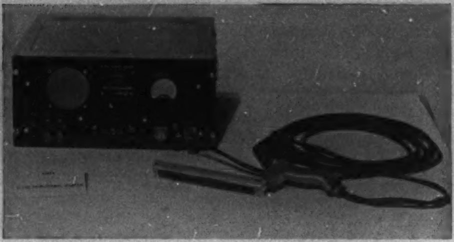

Figure 5. An alpha proportional counter—"poppy"

The OH radical is highly reactive as an electron acceptor and it is this reaction which probably accounts for the fact that almost all organic compounds are decomposed by irradiation in aqueous solutions. The H radical is probably less reactive than the OH radical with most organic molecules.

Cell Poisons. It is likely that some products of cell decomposition produced by radiation may be injurious in quite low concentrations. This possibility has not been studied extensively and few facts are available to prove this mechanism. Recently G. Hevesy has shown that in the case of two neoplasms growing in the same animal, if one tumor is radiated there is a decrease in the nucleic acid turnover in both tumors. This neoplastic growth-inhibiting mechanism may be a chemical substance and not resulting from tissue ionization directly.

Specific Ionization. Even with a small over-all dose of ionization there will be, along the paths of ionizing particles, areas of dense ionization. This will occur especially along the tracks of alpha particles, protons, and slow electrons. Thus it is possible to produce structural changes which at times may become microscopically observable. The best example of this type of effect is the breakage of chromosomes by radiation. For the production of this effect, about 20 ionizations are necessary over a distance of one-tenth micron.

Direct Action Upon Large Molecules. The dose required to produce chemical changes in a given proportion of the molecules of a substance by direct action is roughly inversely proportional to the molecular weight. As a working rule, a dose of 10^6 roentgens will produce chemical change in half the molecules of a substance of molecular weight of 10^6.

The small viruses appear to be proteins of very high molecular weight. Genes, the physical entities corresponding to a Mendelian character, are considered to be nucleoproteins of large molecular weights. Inactivations or damage of these large molecules can be explained adequately on the basis that a chemical change in the molecule occurs whenever one or more ionizations are produced in it.

There are some effects of radiation on higher cells which are believed to result from the direct ionization of large molecules in the cell. Gene mutations are the most striking examples of this type of radiation effect.

This review of the many possible ways in which ionizing radiations may be effective indicates that the effects of these radiations may depend to some extent upon the type of radiation employed. Ionizations produced by X rays up to one million electron volts and by gamma rays will be fundamentally alike. Protons and alpha particles may produce biologically different results because of the differences in specific ionization. These considerations have been amply confirmed by animal experimentation.

Biological Effects of Ionizing Radiation. The reactions seen following exposure to X rays can be divided into skin effect, blood changes, and genetic effects.

Skin Effects. The skin may be considered to consist of essentially two layers: the epidermis and the dermis. The epidermis is the horny layer, forming a protective cover, whereas the dermis contains blood vessels, nerve cells, multiplying epithelial cells, and hair follicles. The epidermis varies in thickness from 0.03 to 0.15 millimeter with even greater thickness over the palms of hands and soles of feet.

Penetrating radiation will produce changes in the dermis resulting in irritation, damage, or destruction of the vital cells of the skin. If sufficient number of cells in the dermis are destroyed permanently, there will result ulcerations, which in some cases progress to cancer of the skin. Response of the skin to different dosages of radiation is shown in Table II.

Blood Changes. Much work has been done concerning the changes in the blood-forming organs and in peripheral blood following exposure to radiation. It has been known for many years that the bone marrow is a very sensitive organ and that consequently early effects of radiation injury can be found by studying the peripheral blood count. Unfortunately, the blood count is influenced by many different factors such as fever, infections, drugs, food intake,

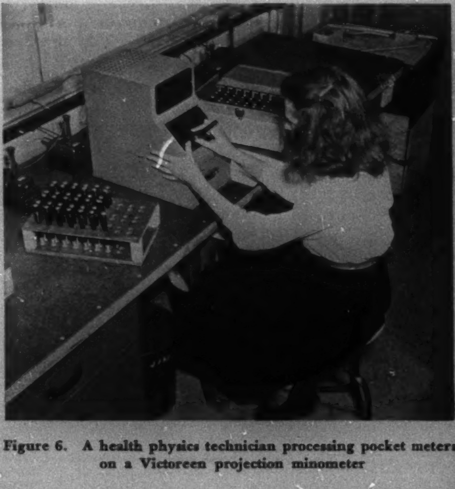

Figure 6. A health physics technician processing pocket meters on a Victoreen projection minometer

and physical exercise, making the results of a single examination frequently difficult to evaluate.

The complete blood count consists of an estimation of hemoglobin, usually expressed in terms of percentage of the normal, the number of red blood cells and the number of white blood cells and blood platelets. The white blood cells can be divided into several groups, the most important of which are the polynuclear cells and the lymphocytes. Early changes usually are seen only in the number of white blood cells, whereas changes in the red blood cells, recognizable as anemia, are seen in the more severe cases of radiation exposure, such as the atomic bomb victims.

In addition to the many factors which can influence the blood count, there exists a peculiar sensitivity of the bone marrow towards certain injuries. It has been found, for instance, that a small number of people is highly sensitive to ingestion of certain benzol derivatives contained in many popular drugs. Such sensitivity is manifested by serious disease, called agranulocytosis, and in those people the white blood cells may disappear almost completely from the peripheral blood. This peculiar type of reaction of the bone marrow always should be kept in mind, because it is possible that a group of people may show a similar sensitivity to radiation. For that reason it is necessary to keep the amount of exposure at as low levels as possible and to examine the blood smears of radiation workers at frequent intervals.

Genetic Effects. The mechanism of genetic changes following ionizing radiations has been mentioned briefly. The effects can be produced by a direct ionization of genes or by a breakage of chromosomes in which the genes are located.

The changes resulting from damage to genes generally are spoken of as mutations and may occur as result of disturbances of many kinds. As it has been found that the vast majority of mutations are harmful, we certainly do not wish to increase this process knowingly. Constant protection against the action of ionizing radiation and utmost care in the disposal of radioactive materials therefore are indicated for all workers in this field. Until much more is known about the frequency with which genetic changes following radiation occur in the human race, one hardly is justified to speak of a tolerance dose for ionizing radiation. Instead, the term "maximal permissible dose" has been proposed and a continued effort should be made to lower this dose by means of improved protection.

Table III shows the approximate amounts of the so-called natural radiation and some biological effects of low dosage radiations.

Table III. Approximate Amounts of "Natural Radiations" and Some Biological Effects of Low Dosage Radiations

Dose per Day, Roentgens	Radiation or Biological Effect
0.0001	Cosmic rays at sea level
0.001	Radiation from normal amount of radioactive substances in nature. Cosmic rays at 4,000 meters
0.01	0.1 microgram radium in skeleton. Blood changes probable after considerable time
0.1	1 microgram radium in skeleton. Blood changes confirmed. Decreased sperm count in dogs
1–10	Skin reaction probable after considerable time. Shortened life span of experimental animals

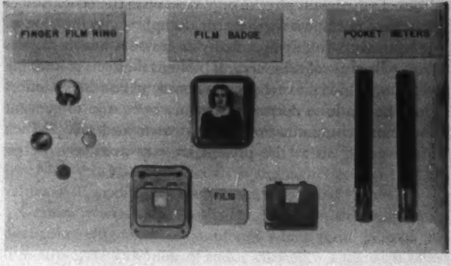

Figure 7. Personnel monitors showing the component parts of a finger film ring, film badge, and pocket meter

Carcinogenic Properties of Radiation. It has been known for many years that X radiation of the skin, if given in sufficient amounts, can produce skin cancer. A similar effect can be obtained with ultraviolet radiation. In addition, the degenerative skin lesions following radiation, such as atrophy and ulceration, may turn into skin cancers many years following the original injury.

It further has been found that in experimental animals, such as mice, cancers of the ovaries can be produced by repeated low dosage radiations and by single exposures.

Leukemia, a cancer of the white blood cells, also can be brought on by radiation in experimental animals. Statistical studies tend to indicate that the incidence of leukemia among roentgenologists may be from three to five times as high as is found among other members of the medical profession.

Human experience with radium and animal experiments with similar products have shown that these alpha emitters, after having entered the body through the lungs or through the skin as a result of small wounds, tend to localize in the bone marrow. They are capable of producing at least three lesions:

1. Sarcoma of the bone.
2. Destruction of the blood-forming organs resulting in aplastic anemia.
3. Cancer of the lung.

Unfortunately, it has been found that only minute amounts of these materials are necessary to produce these most serious disorders.

Because of these serious biological effects of ionizing radiations, a continued effort should be made to decrease exposure rates and to prevent unnecessary contamination of air, water, and soil.

SUMMARY

The discussion of the physical and medical aspects of radiation hazards as presented here is by no means complete. If this treatise of a rapidly developing science can serve to acquaint the reader with the fundamental organization of a group actively engaged in radiation protection, it has fulfilled its purpose. As the field of atomic energy develops, the practice of health physics and its associated sciences likewise must develop. Primary in the responsibilities of any health physics organization is the education of the worker to respect the hazards, to appreciate the control system, and to qualify eventually as his own health physics agent. Because of these serious biological effects of ionizing radiation, which have been discussed, a continued effort should be made to decrease exposure rates and to prevent unnecessary contamination of air, water, and soil. Much work is going on at the present time to achieve a better understanding and to find more complete knowledge concerning the biological effects of these radiations.

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Modified Slip Test for Experimental Study of Synchronous Reactance

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MEMBER AIEE

The modified slip test permits a detailed investigation of machine constants under more reliable conditions and embodies several desirable features in the special field of power laboratory instruction.

It is well known that the conventional cylindrical rotor theory of synchronous machine performance is not directly applicable to salient-pole machines. The discrepancies resulting from application of this theory to such machines especially are marked when calculations are made to evaluate the load or torque angle for synchronous motor performance. Blondel's method of attack through the 2-reaction analysis,[1,2] accounted for the marked difference in the reluctance of the magnetic circuit along the field axis and in quadrature thereto, by separating the stator magneto motive forces into the two components acting along these axes, and evaluating their separate effects with due regard to the related permeances involved. The work of R. H. Park and B. L. Robertson[3] and that of R. E. Doherty and C. A. Nickle,[4,5] led to a further development of this method by expressing the effects of Blondel's direct and quadrature magnetomotive forces in terms of corresponding synchronous reactances. These two reactances, specified as the direct- and quadrature-synchronous reactances, are quite analogous to the classical synchronous reactance concept developed for the unsaturated cylindrical-rotor machine by Charles P. Steinmetz. The concise and explicit results embodied in this 2-reactance development are a tribute to the original authors of this work.

For purposes of discussion, Figure 1 shows the components of the stator magnetomotive forces resulting from balanced load currents, as well as the markedly different reluctance of the two magnetic circuits associated with these magnetomotive forces for a salient-pole machine. As in the usual conventional development, the effect of magnetic saturation is neglected initially so that superposition of the two separate effects can be considered. Thus, the magnetomotive forces A_d and A_q are assumed to be replaced by the fields they produce, and these fluxes in turn evaluated in terms of electromotive forces which are then equivalent to the direct- and quadrature-synchronous reactance voltage components. The form of the vector diagram presupposes sinusoidal time and space variations. It might be mentioned also that the space (and time) vector A is fixed with respect to the field system, the angle between A and A_q being related to the so-called internal power factor of the machine. Inspection of Figure 1 also should reveal that

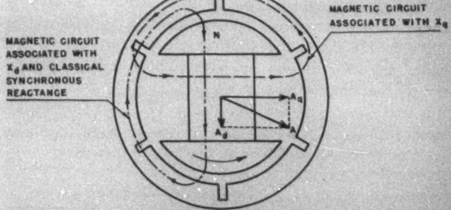
MAGNETIC CIRCUIT ASSOCIATED WITH X_q
MAGNETIC CIRCUIT ASSOCIATED WITH X_d AND CLASSICAL SYNCHRONOUS REACTANCE
N
A_q
A_d
A

Figure 1. Stator magnetomotive forces with balanced load currents

A—Magnetomotive force from lagging load current
A_d—Direct component of load magnetomotive force
A_q—Quadrature component of load magnetomotive force

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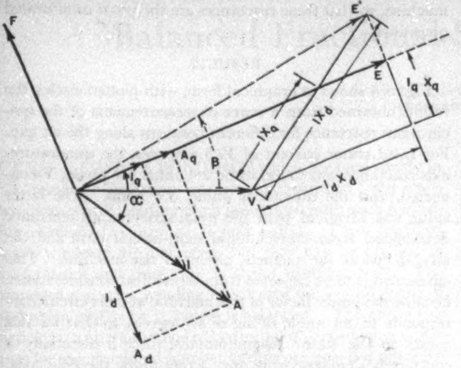

Figure 2. Vector diagram for a salient pole machine

the direct-axis reactance is practically the same as the conventional synchronous reactance associated with cylindrical-rotor theory and determined experimentally from short-circuit data. Under the conditions of the short-circuit test, the stator magnetomotive force will be directed in space so that A is collinear with A_d, and the entire magnetomotive force acts along the field axis.

Figure 2 represents the vector diagram for a salient-pole machine, simplified by neglecting the relatively small effect of stator winding resistance A simple geometrical construction[6] permits the determination of the internal electromotive force E without evaluating the two components of the load current i_d and i_q usually associated with X_d and X_q. The diagram also serves to illustrate the different results obtained by using the usual synchronous reactance construction, as well as the Doherty and Nickle method. The magnitudes of the two internal electromotive forces are approximately the same for the two instances, as indicated by E and E', but the angles between these alternative electromotive forces and the terminal voltage are quite different. It is this quantity, indicated by β, which is critically related to the behavior of the synchronous machine under load.

SLIP TEST

When experimental values of X_d and X_q are of interest, these quantities can be determined by means of the so-called slip test. This early and ingenious method of test appears to have been proposed originally by Haga,[7] in conjunction with the pioneer work of Blondel. In simple terms, the basis of this test is to establish a slightly asynchronous relation between the (mechanically) rotating field system and the (electrically) rotating stator magnetomotive force. As the stator magnetomotive force slips past the rotating field structure, the difference in reluctance along the direct and quadrature axes, causes a periodic variation of stator current, and if this slip speed is low enough, the maximum and minimum values of this current variation can be read on the line ammeters. An alternative but tedious method is to obtain an oscillographic record of this variation. In either instance, the experimental arrangement involves driving the salient-pole field structure of the test machine at approximately synchronous speed, and adjusting the frequency of the current supplied to the stator so that the angular velocity of the stator magnetomotive force is slightly more or less than that of the rotor. An alternative arrangement could be that of a synchronous motor drive, with a variable and slightly asynchronous voltage supply for the test machine. In either test the field circuit is demagnetized so that the values of X_d and X_q are the usual unsaturated values.

Generally when this test is conducted in the laboratory, disturbing effects are encountered which tend to mask the true slip-cycle variation of stator current. One such effect can be caused by hunting—a condition resulting from the pulsations of magnetic reluctance inherent in the construction of the rotor. These pulsations give rise to periodic variations of load torque, which change the instantaneous speed of the driving unit, particularly if the latter machine is of about the same rating as the test machine. Under these conditions the readings of the extreme swings of the ammeter pointer give unreliable results. Another consideration has to do with the fact that if the mechanical speed is not held extremely constant, there is always the tendency for the rotor to become magnetized by induction at the low slip speed, and pull into step. The test machine then runs as a synchronous-induction or hysteresis motor and the slip phenomenon disappears. When proper test conditions have been established, the extreme variations of stator current frequently introduce related voltage changes of the source, so that both voltage and current swings must be read simultaneously. It also will be found that the extreme deflections of the instruments are related to the inertia and damping characteristics of the meters, so that all the line ammeters will not read alike.

MODIFIED SLIP TEST

A modification of the usual slip test can be used to advantage in special cases, giving more reliable data and permit-

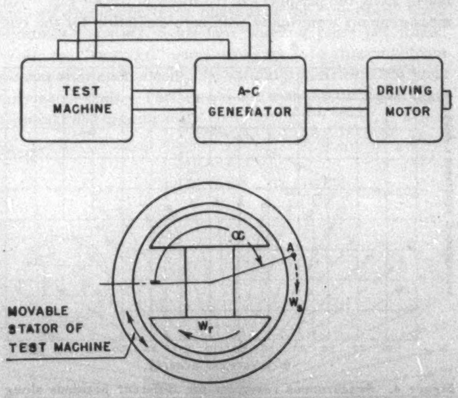

Figure 3. The connections of the modified slip test

ting a more detailed investigation of the various factors affecting the reactances under review. In particular, this modified slip test possesses pedagogical advantages when the 2-reactance theory for synchronous machines is investigated in the power laboratory. The tests described herewith, involved the use of a 3-machine set consisting of a d-c motor coupled to two 15-kva 220-volt salient-pole 3-phase synchronous machines, one of which was so constructed that its stator could be turned through a space angle corresponding to approximately 130 electrical degrees. By supplying the output of the fixed-stator unit to the movable-stator machine, it is evident that complete synchronism exists between the traveling magnetomotive force in the stator of the second machine and its rotating field structure. The relative position of this magnetomotive force with respect to the salient-pole field structure then could be controlled by shifting the stator frame of this machine, so that the entire variation of synchronous reactance along the pole arc could be measured. For any fixed position of the stator, any instruments in the circuit can be read without the disturbing effects mentioned previously, as all the readings are taken under steady-state conditions.

The general scheme of connections involved in these tests is indicated in Figure 3. Because the two a-c machines are always in electrical and mechanical synchronism, the angular velocity ω_r of the field structure is equal to ω_s, the angular velocity of the stator magnetomotive force. By shifting the stator in its frame, the angle α can be varied so that the stator magnetomotive force acts at any selected point such as *A*, around the periphery, and its effect evaluated in terms of a synchronous reactance for that specific stator magnetomotive force location. The value of this reactance will vary from a minimum for $\alpha=0$ or 180 degrees (representing X_q); to a maximum for $\alpha=90$ or 270 degrees (corresponding to X_d). The angle α was measured by reading the position of a graduated scale on the movable stator, with respect to a fixed index pointer. Reference angles corresponding to $\alpha=0$ and $\alpha=90$ degrees could be checked by means of stroboscopic observations of the synchronously rotating field structure with respect to reference marks along the periphery of the stator at the air gap. All measurements were made with zero excitation for the test machine, so that these reactances are the usual unsaturated quantities.

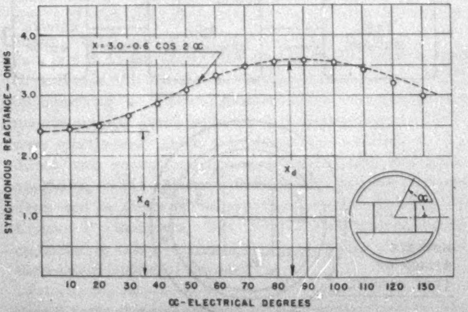

Figure 4. Synchronous reactance for different positions along the air gap

RESULTS

Figure 4 shows in graphical form, with plotted circles, the results obtained from a series of measurements of the synchronous reactance for different positions along the air gap. For rated stator current of 39.5 amperes, the quadrature-axis reactance was found to be 2.4 ohms per phase, Y-connected, and the direct-axis value, 3.6 ohms. The latter value was identical with the usual synchronous reactance determined from conventional short-circuit data and the air-gap line for the magnetic circuit of the machine. This agreement is to be expected from theoretical considerations, because the power factor of this machine at short circuit corresponds to an angle of lag of 86 degrees, so that for this condition the stator magnetomotive force is essentially a completely demagnetizing one, acting along the field axis.

A simple analytical expression can be written for the experimental variation obtained, by noting that the reactance varies symmetrically about a constant value of 3.0 ohms, as a cosine function of the double angle of shift. The angle α indicated on the small sketch shown in Figure 4 is merely a symbolic specification of electrical angle, as the unit tested was actually a 6-pole machine. The analytical form given and shown by the dotted curve, is in close agreement with experimental data, indicating a rather exact sinusoidal variation of air-gap permeance for this machine.

VARIATIONS

An objection may be raised to the elaborate experimental arrangement required for this test, although this type of set frequently is found as standard equipment in engineering school power laboratories. However, it might be mentioned that this test could be performed with a 2-machine set, if the test machine had a movable stator, and the driving unit were a synchronous motor. In this instance, the same a-c supply would have to be used for both machines, and some means might have to be provided for adjusting the voltage for test requirements. Finally, the movable-stator feature in this 2-machine set also can be dispensed with, by employing a coupling device having its two halves movable with respect to each other. Except for the necessity of stopping the set each time a shift of the two halves of the coupling is made, (corresponding to a different value of the angle α), this arrangement permits the same range and flexibility of experimental investigation as that described previously. In these tests, it also might be mentioned that the functions of the test machine and a-c generator could be interchanged, with some possible practical advantages.

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Balanced Fractional-Slot Wave Windings

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THE A-C WAVE WINDINGS which are used mostly in rotors of induction motors are "modified" d-c wave windings whose winding pitch is changed after each p winding elements (p=number of pole pairs). These modified wave windings are balanced, but they can be applied to integral-slot and (integral+1/2)-slot windings only. The standard d-c wave winding is not used for wound rotors of induction motors for it seldom is balanced. The aim of this article is to give a method of laying out balanced wave windings for any fractional number of slots per pole per phase for which the fractional-slot lap winding is balanced. For this purpose the usual chart method is to be abandoned and the slot-star of the winding used instead.

If the number of slots per pole per phase is written

$$q=\frac{N}{\beta}$$

where N and β have no common divisor, β is the number of poles in a repeatable group of the winding and N the number of slots per phase per repeatable group. $2p/\beta$ is the number of repeatable groups. The slot star shows the position of the slots in the magnetic field. There are as many vectors in the slot star as there are slots in a repeatable group, that is, mN vectors (m=number of phases). Figure 1 shows the slot star of a 3-phase winding with $1^{4}/_{5}$ slots per pole per phase. For this winding, $N=9$ and the number of vectors in the slot star is 27.

The vectors of the slot star follow the series 1, $1+d$, $1+2d$, $1+3d$, ...; where d is given by the equation

$$d=\frac{mNP+1}{\beta}$$

P is the smallest integer which makes d an integer. If a number of the d-series becomes larger than mN, this quantity is to be subtracted from the number.

Maximum distribution factor for the main wave is obtained, if the slots assigned to each phase lie as close together as possible, for example, if in Figure 1 the first $N=9$ slots are assigned to phase A, the following 9 slots to phase C, and the last 9 slots to phase B. Then the slots occupied by phase A in the first repeatable group are 1, 12, 23, 7, 18, 2, 13, 24, 8. The slots occupied by phase C are 19, 3, 14, 25, 9, 20, 4, 15, 26, and so on. However, it is not necessary to draw the slot star, in order to find the slots occupied by the three phases. Vectors of the slot star follow the d-series, and consecutive numbers of this series yield the same result as the slot star.

In the fractional slot wave winding, the same slots are assigned to the three phases as in the fractional slot lap winding. However, in the latter winding, two consecutive upper conductors lie in adjacent slots, while in the wave winding two consecutive upper conductors must lie y slot pitches apart (y=winding pitch), that is, the consecutive upper (or lower) conductors of the wave winding must follow the y-series 1, $1+y$, $1+2y$, $1+3y$, ...; where

$$y=\frac{2mN+a}{\beta}$$

in which a is the smallest integer which makes y an integer, and a can be postive as well as negative.

The problem of laying out a balanced wave winding consists in the co-ordinating of the d-series and y-series of the winding. Because each p coil of the wave winding goes around the whole rotor or stator, consideration of the wave winding cannot be limited to one repeatable group but must comprise all $2p/\beta$ repeatable groups, all $2p/\beta$ slot stars or all $2p/\beta$ d-series must considered simultaneously. The vectors of the $2p/\beta$ slot-stars coincide. Therefore if the $2p/\beta$ d-series are written one above the other, the $2p/\beta$ conductors which lie in the same column are in phase and can be substituted one for the other. This fact facilitates the co-ordination of the d-series and y-series. Applying this to the winding of Figure 1, the d-series of phase A are

1, 12, 23, 7, 18, 2, 13, 24, 8,
28, 39, 50, 34, 45, 29, 40, 51, 35,

and the y-series of phase A

1, 12, 23, 34, 45, 2, 13, 24, 35,
28, 39, 50, 7, 18, 29, 40, 51, 8

The magnitude of a determines the number of winding parts in each phase. For the winding of Figure 1, $a=1$ and there are two winding parts per phase as in the "modified" wave windings. $a=\pm 2$ yields four winding parts per phase. While the "modified" wave windings have abnormal front pitches after each p coils, the windings just described have only equal coils. This makes the manufacturing of these windings less expensive.

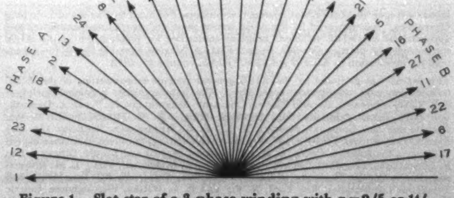

Figure 1. Slot star of a 3-phase winding with q=9/5 or $1^{4}/_{5}$

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System Overvoltages Caused by Faults and Switching

AN AIEE COMMITTEE REPORT

POWER SYSTEM OVERVOLTAGES may result from lightning, switching, faults, loss of load, and other causes. An understanding of the phenomena associated with all causes of overvoltages is necessary to control the magnitude and to co-ordinate the protection and insulation levels of the system. Lightning may be considered the chief source of high overvoltages. Much attention and study has been and continues to be given to all lightning phenomena and means of protection. Next and of increasing relative importance are the overvoltages produced by faults and switching surges. Considerable study has been given this subject during the past 25 years and it is opportune to review the literature on power system overvoltages produced by faults and switching surges which includes results obtained from field tests; the phenomena that control cumulative oscillations and restrikes; and the results obtained by the miniature system of analysis which show the influence of grounding, arrester location, and circuit breaker interrupter restriking. Such a review prompts a number of conclusions which indicate the progress and understanding of the subject to date and which also may serve as a guide to future investigations.

These conclusions can be summarized as follows.

1. Maximum switching surge voltages on overhead lines or cables are the consequence of the interruption of fault currents and/or the de-energization of an essentially capacitive circuit.

2. Maximum switching surge voltages of six times normal may be experienced on overhead lines. The maximum values experienced are limited perhaps by the flashover of insulators or bushings on systems where there is no arrester operation from switching surges.

3. Maximum switching surge voltages of $3^1/_2$ times normal may be experienced on cable systems in which no arrester operation is involved.

4. Items 2 and 3 of the foregoing are based largely on data accumulated since 1924 from measurements using gaps or the "Lichtenberg" figure principle of measurement and which therefore are of limited accuracy.

5. Transient overvoltages incident to the operation of electric furnaces are similar to the surges experienced on an overhead line except for the increased frequency of occurrence. The highest magnitudes appear to be associated with circuit breaker opening operations.

6. Direct evidence to date indicates that switching surges of the greatest severity on systems occur only from circuit interrupting devices wherein a process of cumulative restriking of an arc occurs at successively higher voltages as the result of an increasingly greater dielectric recovery strength. No direct evidence exists that this process occurs from arcs in open air or in solids.

7. There is no evidence to date to indicate that the nonlinear characteristics of the arc enters in as an important factor in system overvoltage.

8. One method of measuring system-recovery voltages uses a miniature system. The system under consideration is set up in miniature with sources of voltage and lumped constants of inductances, capacitance, and resistance to represent corresponding elements of the actual power system. Circuits with distributed constants are simulated by combinations of lumped inductance and capacitance elements. Switching operations are performed on the miniature system which correspond to the circuit changes to take place on the actual system.

Perhaps the principal advantage of the miniature system method is that it provides a rational approach to the problems of overvoltages to be expected for a wide range of system constants and grounding impedances. Results of this approach are more understandable and, no doubt, more useful than could be obtained from field data which are incomplete because such data cannot cover a great range of system constants or switching conditions.

9. Results from the study of systems in miniature show that the magnitude and severity of the switching surge may be reduced by the following:

(*a*). Effective grounding of system neutrals

(*b*). Rational application of voltage arresters

(*c*). Switching short sections of line

(*d*). Switching lines or cables on the low-voltage side of the transformers

(*e*). Switching with stored-energy-type circuit breakers or with resistance shunting of the circuit breaker contacts

(*f*). Switching with circuit breakers designed to interrupt charging current with not more than one restrike

10. In arrester-protected systems, the switching surge voltage should not exceed approximately the 60-cycle sparkover voltage of the arrester. For a solidly grounded system ($X_0/X_1 = 3$) this value is about 2.5 times normal line-to-neutral voltage.

11. In arrester-protected systems involving long lines, the severity of arrester discharge from switching surges can be of primary importance as compared with probable lightning surge discharges.

12. In arrester-protected systems the switching surge does not appear to be an important determining factor in the insulation requirements of apparatus or lines.

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Network Theory Comes of Age

R. L. DIETZOLD

The third decade in the growth of modern network theory, the decade of maturity, is considered in this review of the advances in network theory evolved over the past ten years. New types of networks developed during the war are included.

THE BIRTH of modern network theory may be dated fairly from the discovery in 1917 of the electric wave filter by George Campbell[1] in America and Karl Willy Wagner[2] in Germany. Its subsequent growth falls into three phases, fitting well into a decade of infancy, a decade of adolescence, and the decade of maturity which is here under review. In each phase we easily can discern the attributes appropriate to the age of the theory, and are not surprised to find the period of its 20's marked by disillusion, uncertainty, and a good deal of romancing around with other theories. The offspring of these wartime amours are already sturdy little theories which may turn out to be more interesting than the parents.

THE FIRST DECADE

Artificial Lines and Filters. We can understand this period better by first recalling what network theory was like in its youth. Its first ten years were characterized by the rapid proliferation of useful devices. These stemmed directly from the germinal discovery that the lumped element analogue of the continuous line enjoyed properties of high selectivity. As the lumped element system enjoyed also greater freedom, we had immediately extensions from the low-pass case to high-pass, band-pass, and all-pass configurations, followed soon by extensions from simple iterative structures to complex aggregates utilizing Zobel's *m*-derived sections with their useful impedance and attenuation properties.[3] The theory of this period was the image parameter theory, taken over from the well-established theory of the continuous line with so little generalization that it was grasped quickly by everybody and led to prompt and valuable applications. The spirit of the period was to catalogue the performance of simple "sections," and the rules of combination, and then to undertake the construction of a network edifice by making a judicious choice of these building-blocks. The title of A. C. Bartlett's book, "The Theory of Artificial Lines and Filters," epitomizes the decade of network theory's infancy.[4]

THE SECOND DECADE

Dynamical Theory. The increasing sophistication of the second decade shifted the interest from the discovery of devices to the discovery of network properties. It was seen that the general network, with many accessible terminals, was not modelled on the continuous line, and the image parameter theory was dropped. The alternative theory already was made for the vibratory systems of particle dynamics.

Taking over the concepts and methods of classical dynamics quickly made network theory seem a little more like physics. Classical arguments from energy considerations led R. M. Foster and W. Cauer to the conditions for physical realizability for 2-terminal networks of two kinds of elements, the sufficiency of which they demonstrated by finding the networks.[5,6] The case of three kinds of elements was stickier. Nevertheless it was solved triumphantly by Otto Brune.[7] The extension of Brune's work to the two terminal-pair network was achieved successfully by C. M. Gewertz.[8] A further generalization to the *n*-pole network would have been quite in keeping with the times. However, it was only recently that this case first was treated; a compact solution should appear in the course of the year.

These fine results were not achieved without taking over the methods as well as the concepts of mathematical physics. Matrix algebra supplied a compact notation for the description of systems with many degrees of freedom, and for the discussion of equivalence under linear transformation of the variables. This seemed to Howitt[9] and to most of the rest of us to offer an easy identification of families of equivalent networks. The algebra is all right, but it ignores the geometrical aspects of networks. We are indebted to Foster and to Kron for emphasizing the topological features of networks.[11,12] To avoid the geometrical consequences of linear transformations, Cauer found it necessary to resort to ideal transformers, as he shows in a fine paper of similar title.[13]

Although the equivalence theory turned out to be of little use, the ideas stimulated Guillemin to propose the principle of duality, which freed network theory of bondage to the mesh impedance analysis, and opened the door to the formulation by nodal admittances, so often more convenient.

The search for network properties naturally prompted the use of a good deal of function theory, as well as the algebra and geometry. A conspicuous contribution of analysis was the "loss-phase" relations, which express the interdependence of the real and imaginary components of analytic functions. Such propositions were stated by Lee in his paper dealing with Fourier transforms of Laguerre functions,[14] and later worked into a sharp and handy tool for network design by Bode.[15]

It would be wrong to leave this decade without mentioning that interest in general properties of networks by no means precluded the development of networks for useful purposes. Between them, Cauer and Bode very nearly demolished the problem of filter design on the image parameter basis. Cauer, capably interpreted for the American

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audience by Guillemin, introduced the Tchebychev type of approximation as particularly appropriate to network problems, and it has been embedded firmly in the art ever since.[16,17]

It remained for Darlington to recast the problem of filter design on the basis of insertion loss. I would like to attract special attention to Darlington's paper, which, like almost everything else I have referred to, appeared in that veritable mine of network papers, the Massachusetts Institute of Technology *Journal of Mathematics and Physics*.[18] I do this not only because there is such store of good network theory in the paper, but also because it seems little known. By a few years after its publication there were at least two independent announcements of Darlington's theorem that any physical 2-terminal impedance has a representation as a single resistance shown through a purely reactive network. Why the "Synthesis of Reactance 4-Poles" might be neglected is explained by George VI of England. In a wartime inspection of a British laboratory, the King paused at the desk of an engineer who was pouring over Darlington's paper. Picking it up, he studied a moment, and said, "Good Lord, can you understand this?" I guess network theory is kind of hard.

THE THIRD DECADE

Time Versus Frequency Response. As the second decade was turning into the third, we were pretty sure we did understand at least what network theory was about. It was the theory of lumped, linear, passive systems in the sinusoidal steady state. As such it happily had been developed by people primarily concerned in the transmission of sound, and interested exclusively in frequency response. However, critics were arising among people with pictorial information to transmit, who were more concerned with the time response of networks. We heard argument as to whether "square-wave testing" or "steady-state testing" yielded really fundamental data. Even the universities dignified this barrier by distinguishing transient analysis from network theory; transients came in circuit theory. The theory really came of age when all finally agreed that this is one flesh, and recognized what Laplace had seen 150 years earlier; namely, that the frequency response and the time response are quite easily interchangeable, and both are important in analysis. In both camps men paused for another look at the old formulas

$$E_2(t)=\frac{1}{2\pi i}\int_{-i\infty}^{i\infty}S_1(p)Y(p)e^{tp}dp$$

$$=\int_{-\infty}^{\infty}E_1(\tau)A'(t-\tau)d\tau$$

which express the same response provided S_1 is the mate of the excitation E_1 and A' is the mate of the frequency characteristic Y.

What they noticed here prompted several lines of inquiry. For one thing, the second equation defines the output signal as the average over past time of the input signal, weighted according to the impulse response of the network. This suggested the concept of the low-pass filter as an averaging network; an immediate application arose in the smoothing of data supplied to the electric computers so widely used for fire control during the war. For efficient weighting of the data, very accurate shaping of the network characteristic is required; for this the design techniques of the steady-state theory were at hand.

The role of the smoothing filter is simply the protection of the signal against noise. This problem has broad general aspects, some of which received close attention. The acceptance band of the radar receiver which maximized the signal-to-noise ratio for pulses of a given shape and duration was defined carefully. I cannot refrain from mentioning this, although it is rather beyond the purview of proper network theory. This is a matter of information theory, a child born of the union of network and circuit theory, which seems already wiser and more worldly than its parents.

However, a second inquiry prompted by the formulas fell wholly within the domain of network theory. Some wondered what kind of steady-state characteristics could be made available by a device which mechanized the convolution integral. Such devices require storage of information during the time interval over which the integration is to be extended. They are pictured easily, although somewhat awkward in the realization. Wiener and Lee stored the input signal on a delay line, with arrangements for picking off the voltage at intervals along the line and summing appropriate fractions of them, according to the desired weighting function. Others preferred to store in electron beam tubes of special design, introducing the weighting by rasters of one sort or another, as in the arrangement Kallman called the transversal filter. As many of the simplest weighting functions correspond to complicated steady-state characteristics, it is possible that these intriguing novelties may prove one day to be of use.

Active Networks. If the marriage with circuit theory served to broaden the outlook of network engineers, the marriage with electronics pushed back the horizons much farther. The outstanding advance of the period was the extension of the theory from passive to active systems. It is indifferent to the theory by what means the energy release is accomplished, but usually the means is electronic. The inclusion of vacuum tubes as network elements created new problems and afforded new properties. Stability, assured in the passive case, now had to be wooed with skill and acumen. Bode exploited Nyquist's criterion and the loss-phase relations to establish limits on the feedback consistent with stability for a great variety of cases of practical importance. The new property, discovered by Harold Black, is essentially the enormous range in sensitivity of the external behavior to variations in the internal elements, depending upon the location of the element in the network. This property has been turned to such good account in the negative feedback amplifier that repeaters having nearly the reliability of passive networks are available for telephone systems.

Despite the inclusive nature of Bode's book, there remain gaps in the theory of active linear systems which we may hope to see filled within the coming decade. We inquire in particular if multiloop feedback connections cannot be employed to avoid the stability limitations on multistage feedback.

Accommodation of Parasites. The introduction of vacuum tubes as network elements had an influence on the development of the theory even in the seemingly trivial cases in which feedback deliberately is avoided, the tubes serving only as buffers between passive networks. In these cases the role of the theory is to provide accommodation for the circuit parasites as required elements of the network. As the parasites are predominantly the tube capacities, two typical problems are presented. In the line coupling problem, a signal voltage originating in a resistive source impedance is to be maintained across a limiting input capacity. In the interstage coupling problem, the signal voltage originates in a capacitative plate impedance and is delivered to a capacitative grid impedance. Under pressure to provide noise-free high-gain transmission over ever wider bands, Bode, Wheeler, Hansen, and certainly many others, examined how effective such coupling networks theoretically might be in accommodating the limiting capacities. For the line coupling case, Bode advanced the resistance integral theorem as a concise measure of the physically possible stepup. The interstage coupling case admits a similarly general characterization, independent of band-shape. For a flat band and a 4-terminal coupling network, Bode found a theoretical limit of 2.5 times the gain into the mean of the input and output capacities at a frequency equal to the bandwidth.

These propositions on the gain-bandwidth product do not make the designers of wide-band amplifiers very happy. They sometimes are asked for systems with rise times in the neighborhood of a millimicrosecond, which implies bandwidths of hundreds of megacycles. And only a few of the most modern tubes have intrinsic cutoffs as great as 100 megacycles. The compulsion toward highly efficient networks is greatest when the bandwidth is great, or when the difficulty of accurate measurement and adjustment is also greatest. And the networks which approximate to maximum stage gain are discouragingly complicated and sensitive to adjustment.

There is probably no escape from the sensitivity in highly efficient network designs, but the theory was quick to provide an escape from complexity. If the multistage amplifier is conceived as a combination of identical stages, then each stage must give a very perfect approximation of the required gain shape, and the coupling networks, if efficient, are individually quite complicated. But equal efficiencies in the realization of the required over-all characteristic can be obtained from a combination of shapes, each corresponding to a simple coupling network, provided that the networks are allowed to be all different. Empirically, it is not easy to break up the total characteristic into the appropriate combination of simple shapes, as Feldtkeller discovered. However, when the over-all requirement was an approximation to constant gain, either in the Tchebychev sense or in the "maximally flat" sense, the theoretical decomposition readily was determined. This is the process to which Henry Wallman affixed the catchy name of "stagger tuning." The theory might have been taken over bodily from Darlington, but actually it was worked out the hard way by independent investigators, Wallman, Baum, Bradley, and others. Analytical solutions so far published read only on the several approximations to flat transmission. Means for generalizing the solution to a great variety of useful characteristics are already at hand, and will be described a little later on.

Unhappily, candor compels the admission that this easy triumph of network theory is mostly a Pyrrhic victory, and that the decade actually has left the wide-band amplifier in pretty bad shape. It is quite true that by systematic design of the multistage amplifier the limiting efficiency can be approached with conventional coupling networks. This would be more significant if the theory were tightened up. It goes through beautifully so long as narrow-band approximations obtain; the applications, on the other hand, are usually to relatively wide bands. This case is much less simple; it cries for discussion. One obnoxious detail is the necessity of impedance transformation to insure the most efficient accommodation of arbitrary terminating capacities; in the very wide band cases, as for the video amplifier, this possibility is lost. The dependence of available gain upon the capacity ratio well might deserve some study.

Aside from theoretical inadequacies is the question whether the highly efficient amplifier is really useful. The exchange of efficiency for ease of adjustment and insensitivity to circuit variations invited attention from designers having a little gain to spare. The arrangements for doing this mostly involved the equalization (and stabilization) of the important part of the band by local feedbacks of one kind or another. Illustrative of a number of ingenious proposals is Ferguson's exploitation of an idea of Harold Wheeler's, whereby each plate is coupled resistively to the preceding grid, a long chain being terminated for an image match between stages. Other arrangements were patterned on the ideas of coupling the voltage stages through cathode followers, so that the feedback might neutralize some of the circuit capacities in the useful band.

Actually, however, the villain of this piece is neither the sensitivity of efficient networks nor the frailty of the theory. The real villain is the basic physical limitation on the gain-band product. A good way of evading this restriction will have to be found. The possibility of evading it is demonstrated by Percival's wave amplifier, developed for bands in the microwave region with spectacular success by Pierce. The video embodiment utilizes conventional tubes and artificial input and output lines. It can be urged quite honestly that here is a means for obtaining any gain over any band with tubes of whatever merit. But this means is only for the stout of heart. If a man can be discouraged at all, in the end he will be dismayed by a rule which doubles the size of his amplifier for each six decibels of extra gain. Nevertheless, the wave amplifier points out a new direction; somewhere thereabout will be discovered the way to really wide-band systems.

Asymptotic Formulas. Systems of great bandwidth and low stage gains frequently grew so cumbersome as to present very tedious problems of analysis. Therefore searches were made for asymptotic formulas which express simply the behavior approached as the number of stages becomes very great. To describe systems essentially absorptive in character, the central limit theorem was taken over from probability theory. This indicates that the impulse response, and likewise the frequency response, tends to become Gaussian in shape as the system grows longer and longer. This is a very comforting result, not only because of the analytical convenience of the Gaussian function, but also because this bell-shaped probability curve is a pulse form ideal for many purposes. In fact, this response characteristic is so desirable that it is common to design even simple systems to approximate to Gaussian shaping.

Very complicated systems essentially dispersive in character seem to have been of less interest. Little has been said about them since John Carson wrote about the building up of sinusoidal oscillations in 1924 until Di Toro picked up the subject again in a thorough treatment presented this year. They both find that to obtain an asymptotic formula you need only to invoke Kelvin's principle of stationary phase, and then usually, to look up one of the recent tabulations of Airy's integral.

The Potential Theory Analogue. The decade also witnessed progress in the synthesis of very complicated systems, as I already have mentioned. Shortly before the war, the idea seemed to occur to almost everybody at once that a network function, defined by an array of roots and poles in the plane of a complex frequency variable, is an analogue of the 2-dimensional electrostatic potential obtaining in a plane normal to a similarly disposed array of parallel charged wires. The line charges are all of the same magnitude, being positive for the representation of zeros and negative for the poles.

This analogy serves to sharpen the intuitions somewhat and to determine at once the network equivalent to such an array of lumped charges. It does not advance the design problem, as the complex potential function and the network function are exactly the same thing. If we write

$$e^{\Theta}=\frac{\Pi(z_\sigma-p)}{\Pi(z_\nu-p)}$$

so that

$$\Theta=\alpha+i\beta=\sum_\sigma \log(z_\sigma-p)-\sum_\nu \log(z_\nu-p)$$

it is indifferent whether by Θ we mean the potential or the transmission. I here use the character z to locate the source points where the charges or singularities are situated, and the variable p to locate the field point at which we seek to evaluate the potential or transmission. In the network analogy interest is restricted to field points on a segment of the line $p=i\omega$, corresponding to a range of useful frequencies.

We begin to detect an advantage to the analogy when we come to regard the array of lumped charges as an approximation to a continuous distribution of charge. Evidently, the potential of charge distributed over a cylindrical surface, intersecting the normal plane in some curve C, can be simulated by unit line charges on elements of the cylinder provided that the spacing of the elements near a point on C is made to vary with the charge density at that point. Passing to the continuous charge distribution replaces the summation by the integral

$$\Theta=\oint \log(z-p)W(z)dz$$

where the complex weighting function W is so chosen that $W(z)dz$ is the real charge on the element dz of the contour.

The integral formulation is remarkably efficacious for purposes of both analysis and synthesis. The design problem becomes the determination of the charge density along a selected contour so that the potential conforms to a prescribed transmission function Θ. This is facilitated by examination of the force field

$$\frac{d\Theta}{dp}=-\oint\frac{W(z)dz}{z-p}$$

If now C is a closed contour within which W is analytic,

$$\oint\frac{W(z)dz}{z-p}=2\pi iW(p)$$

by Cauchy's formula, so that

$$W=-\frac{\Theta'}{2\pi i}$$

For this case, if Θ is defined at real frequencies, W is defined on the contour. The final contour is usually open, but if the requirement applies only to the real part of Θ, it is possible to work with a closed contour and obtain the final distribution from image considerations.

Insuring physical realizability is equivalent to selecting a contour for which the required W corresponds to a real charge density, and which meets the usual network restrictions regarding symmetry and the location of poles. Families of such contours have been found for many useful types of characteristics.

Selection of a particular contour from the admissible family affects the fine structure of the behavior ultimately realized. For after the continuous charge distribution is determined, it is approximated by disposing lumped unit charges along the contour at spacing depending on the density. This introduces a granularity error which may be serious if the contour selected approaches too nearly the real frequency axis at points where the density is low and the lumped charges widely spaced. Of course, the more elaborate the network, the more numerous are the charges to be allocated, and the smaller the granularity ripple becomes. In most instances Darlington's approximation theory can be used to guide the selection of contour for tolerable ripple with a given number of charges.

This approach to the design problem enjoys almost uniquely the feature of being little more tedious for very elaborate networks than for quite simple ones. It first was turned to account in 1938 by Bode and Grossman in the preparation of delay networks to equalize long land lines for television transmission. These networks run to hundreds of elements, and economy in the design effort is essential. In 1940, Cauer provided an exceedingly detailed mathematical background for the theory, but was prevented from publishing his promised paper on the network applications. The analogue subsequently was used by Hansen to explore the gain-band product, and by Bradley in the systematic design of multistage amplifiers.

These accomplishments do not appear to justify the emphasis I have placed on this topic. In fact, they are astoundingly meager. For nearly ten years this field has been recognized as fertile for investigation. It still lies nearly fallow. I believe that the distraction of the war explains it, that the advance only was delayed, and that the next decade will see a rapid development.

Switched Systems. We can find some other clues to the future development by considering the effect on network theory of the rapidly growing theory of information. Information theory sits in the role of referee, judging how well network theory is doing its job. Ultimately, the job of network theory is to insure the most effective utilization of noisy and imperfect media for the transmission of intelligence. We used to believe that this was about the same as achieving perfect equalization and sharp filtering. The referee wonders if we are even on the right track. We long since have seen the equalization problem affected by the introduction of frequency modulation and the limiter. But this is only a tiny step. The introduction of pulse modulation opens the door to greater opportunity. Pulse techniques offer the possibility of reshaping the signal when necessary, in the manner of the telegraph repeater, and lessen our interest in linearity and equalization. Also, pulse techniques lend themselves naturally to time division multiplex, and divert our interest from frequency selective filters. And information theory rules that pulse modulation in fact does supply the efficient solution to many communication problems.

Pulse generation and regeneration imply the addition of another type of element to network theory, namely, the switch. Likely to be only a vacuum tube in the multivibrator connection, it is however not supposed to behave like a linear element, but rather suddenly to alter the circuit when the signal in some branch of the network surpasses a threshold value. A switched system which is governed between transitions by linear laws seems to me to be somewhat more tractable to analysis than other nonlinear systems, and I expect that in the next decade the theory will have some successes. Of course we have seen some already, and we have amassed the requisite fund of information about the way these circuits actually behave from having made so many of them work in the laboratory. It seems inescapable that the theory of the future will be more preoccupied with nonlinear problems.

Many interesting and important achievements necessarily have been omitted from this hasty survey. For this I have no apology; I have put too much in as it is. But I do have to apologize for having given no hint of what a present-day network is apt to be like. The theory may continue to concern itself with schematic representations showing coils, capacities, and resistances, but the things these symbols stand for are likely to have changed remarkably. If the drawing relates to a regulation or control circuit, many of the parts are probably mechanical and the top frequency of interest may be less than one cycle. If, on the other hand, the drawing relates to a wave guide filter, a coil probably stands for an iris edged into a lot of plumbing, and the mid-band frequency is thousands of megacycles With this upward extension of the frequency range, we slowly are crowded away from our fine theory of lumped elements and find ourselves standing again by the door at which we came in, the continuous line.

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Ultrahigh Speed Rotor

A tiny steel rotor that can rotate at 633,000 revolutions per second and produce a centrifugal force 430,000,000 times greater than gravity was described by Professor J. W. Beams, a University of Virginia physicist, before the annual spring meeting of the National Academy of Sciences in Washington, D. C. The rotor, suspended magnetically in a vacuum, is revolved by a rotating magnetic field Maximum rotational speed is limited only by the strength of the rotor material.

Rotors weighing one fiftieth of a milligram to ten milligrams have been used. The highest speeds and centrifugal forces were obtained with steel rotors 0.021 inch in diameter. The low frictional drag makes it possible to drive the rotor in synchronism with a cyrstal-controlled oscillator which should give rotor speeds constant to one part in 100 million.

Switchgear and Circuit Breaker Practice

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IT IS DESIRABLE to review periodically the trend in practice of different types of equipment for the benefit of those who may not be entirely familiar with recent developments in the industry. The following pertinent facts seem to stand out so far as switchgear and circuit breaker practices are concerned.

For low-voltage circuits of 120 to 600 volts air circuit breakers are used almost universally, mounted in metal-enclosed structures. Recent developments include silver line contacts, arc confining arc chutes, selective trip units, and steel panel mounting for which each pole is mounted upon its own moulded base. For 120/208 volts distribution in cities, the use of secondary network systems has become almost universal. The network is fed from transformers through low-voltage circuit breakers called network protectors, and usually are mounted in submersible-type housings.

Circuit breakers and switchgear for medium voltage applications, 2,300 to 15,000 volts, 50,000 to 500,000 kva, are usually magnetic blow out air in metalclad structures, although many oil circuit breakers still are used. Self-contained panels carry instruments, relays, and control equipment. Many outdoor structures in combination with transformers for unit substations are being installed on distribution systems. Steel frame structures are used for the high-voltage side of distribution substations and carry the busses, disconnecting switches, and their connections. Recent developments include standardization of small units which permits assembly of large structures from them (see Figure 1).

Power station switchgear for generating voltage of 13.8 kv as well as 23 to 34.5 kv for indoor service is quite generally metal-enclosed with compressed-air circuit breakers. The kilovolt-ampere interrupting ratings are 500,000 to 2,500,000 kva. The structures include busses, disconnecting switches, and instrument transformers, and some installations have been made in outdoor housings.

There is somewhat of a trend toward elimination of generator voltage switchgear except where required for distribution feeders. In such cases the generating station feeds bulk power to the system at high voltage.

For high-voltage outdoor service at voltages of 46 to 287 kv, the large majority of circuit breakers are metal tank oil with either pneumatic or electric mechanisms, the former being suitable for rapid reclosing which may be as short as 20 cycles. Kilovolt-ampere ratings begin at 500,000 and have been extended to 10,000,000 kva for 230 kv. Scattered installations of high-voltage compressed air and low oil content circuit breaker types have been made, and one operating company recently has ordered nine 69-kv compressed air circuit breakers.

Standard circuit breaker interrupting time for circuit breakers up to 69 kv is eight cycles. For 115 kv and above, both five cycle and three cycle designs are available. New American Standards Association power circuit breaker preferred rating tables are being prepared and will be issued in the near future, covering indoor and outdoor oil and oil-less circuit breakers.

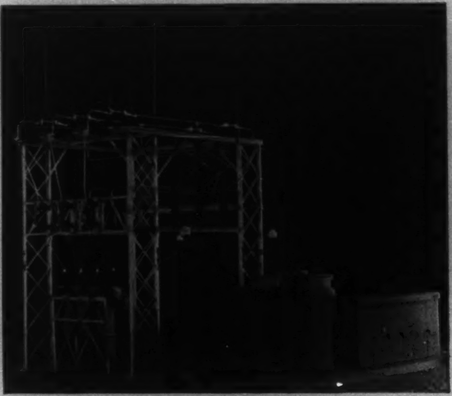

Figure 1. A standardized unit substation with frame structure for high voltage switching equipment, transformer, and metalclad switchgear for distribution feeders

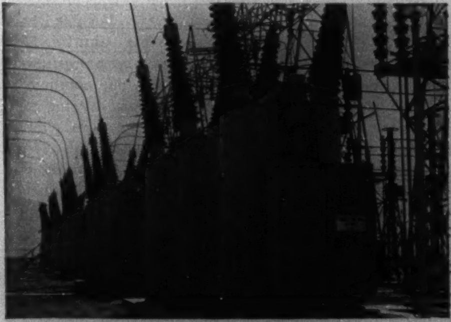

Figure 2. Installation of metal tank oil circuit breakers for 230 kv, 3,500,000 kva

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Digest of paper 48-122, "A Brief Review of Switchgear and Circuit Breaker Practice in the United States," recommended by the AIEE switchgear committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Safety and Aircraft Electric Equipment

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MANY CHALLENGES to electrical engineers came from a conference on aircraft safety which was sponsored by the committee on air transportation at the AIEE winter general meeting in New York, N. Y., January 27–31, 1947. The importance of the subject was summarized aptly by an air line representative when he said, "The complete failure of the electric system in the modern transport must be put in the same category as the loss of a wing." It is evident that aircraft electricity has grown from a role of a convenience to one of necessity. Starting from a system very similar to that used in automotive vehicles, the aircraft electric system has grown until it now more nearly resembles a miniature of an industrial power and distribution network.

Because of the universal interest of all engineers in safety in aircraft, this article presents a summary of the conference on aircraft safety sponsored by the committee on air transportation at the 1947 AIEE winter general meeting in New York. It is to be noted that a number of conflicting points of view were expressed at this conference, which are summarized herein. Further comments are invited.

The multifold purpose of the conference was to stimulate the exchange of ideas and opinions as to how maximum safety in the use of electric apparatus may be achieved, to disseminate information gathered during wartime developments, and to guide and gain support for the program of the committee.

It was a particularly opportune time for such a meeting. While no serious failures have occurred, there has been evidence of enough trouble to cause anticipation of future crises. Study and co-operation now can prevent failures when they will be serious. Groups representing all segments of the aircraft industry aired their problems as never before, and in so doing gave excellent direction for future efforts of the committee.

The aviation industry can be divided into five groups which are concerned with the design, test, and use of electric apparatus:

1. Equipment manufacturer.
2. Power plant manufacturer.
3. Airframe manufacturer.
4. Customer.
5. Civil Aeronautics Administration.

The manufacturer of equipment has primary responsibility for design and test. He receives requirements and specifications from the other four groups and must compete with other manufacturers on performance, weight, and price. The information contained in the specifications is seldom complete and the manufacturer must do a great deal of original research to complete a reliable piece of work.

Engine and propeller manufacturers will use electric equipment, and equally important, their engines and propellers create unusual environmental conditions for many other items of electric apparatus. Even these manufacturers have not been able to predict the nature and magnitude of disturbing forces created by particular models of power plants.

The aircraft or airframe manufacturer assembles the whole. He must satisfy the customer and the equipment manufacturer. Lacking specifications for many items, he must prepare his own. He must develop, procure, and test many special items, so that a complete airplane can be delivered.

There are two types of customers. The military services and the air lines maintain engineering staffs who are familiar with electrical needs, and who specify the performance and design of electric apparatus. In many instances, the equipment is procured and furnished to the airframe manufacturer. However, equipment for personal aircraft is specified and procured by the airframe manufacturer.

The final group is the Civil Aeronautics Administration. The CAA is a friendly umpire who vitally is concerned with air-worthiness, but who does not wish to impede developments in aeronautics. The administration can be expected to take a more active interest in electrical matters as failure of electric equipment more closely concerns air-worthiness.

The customer and ultimate user of the airplane is in the best position to prescribe the needs and requirements of electric equipment. It is this group which will experience the troubles that follow malfunctioning and failure of electric equipment. Unfortunately, it is most difficult to assemble requirements from this group. The military section of the customer group and some of the larger air lines have competent engineering assistance in electrical matters. Other customers, particularly private owners, have no interest in electric equipment beyond that of expecting satisfactory service.

From the mass of data presented at the conference it is possible to present some general conclusions and recommendations. These are given in the following and a more detailed discussion of some problems follows.

It was obvious from many of the comments that the customer group should accept considerable responsibility. However, as it is very difficult for a large portion of this group to contribute effectively, it is necessary to make recommendations which do not completely follow the conclusions. The airframe manufacturer, midway between the equipment manufacturer and the customer, must assume responsibilities for both.

CONCLUSIONS

1. Responsibility for the integration of equipment into an electric system must be accepted by one group. The customer best knows

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the mission of the airplane and is best suited for this position, but the airframe manufacturer is first to assemble the system. Lack of such control has given duplication of equipment, waste of electric power, unnecessary weight, and needlessly complicated circuits, as in the use of similar inverters for individual pieces of apparatus.

2. Protection against failure now is recognized as a fivefold problem. Much work has been done, and apparently adequate answers are available for all known problems. One group must accept the responsibility of requiring the nature and amount of protection. The customer best knows the problems and the penalties.

3. The equipment weight should be ignored. The primary need is that of specifying proper performance and reliability in much more complete detail. Then, let the customer procure and accept equipment on the basis of competitive price and weight.

4. The engineering requirements of aircraft electric equipment have not declined with the end of war. The airplane in peace is still a global traveller and must meet the same environmental conditions as in war.

5. The system guide, conceived and initiated by the air transportation committee is needed badly by the industry.

6. Competition in the design and production of equipment must be fostered to assure greatest engineering progress.

7. The customer group should accept the responsibility of preparing specifications for all types of electric equipment. This group alone knows the operating problems facing the complete airplane.

8. Such standardization of parts to assure interchangeability without impeding progress should be fostered by the customer group.

9. Complicated designs often are condemned unfairly.

10. Standards for limits and method for measurement of radio noise should be prepared as soon as possible. This would appear to be merely a matter of compromising not too different opinions.

11. Manufacturers of little things and of components must conform to the same rigorous requirements as those imposed on the airframe manufacturer. Too often specification requirements have not been handed down to subcontractors and a lowering of reliability has resulted.

12. Customers must develop maintenance material and training.

13. The aircraft operator has not been sufficiently vociferous in the past. Development engineers can produce answers when they know the problems.

A series of recommendations follows from the foregoing conclusions. Only those of general interest are given below. Material for many more detailed conclusions and recommendations will be found in the data which follow, but only those of general interest are given.

RECOMMENDATIONS

1. That the airframe manufacturer group accept the responsibility of specifying system type and nature as well as integrating the various components of the system.

2. That the customer group accept the responsibility of specifying the extent and method of protecting electric circuits and equipment.

3. That an installation code be prepared by the committee.

4. That an environmental standard or a series of such standards be established and published by the committee, so that all manufacturers can have access to requirements.

5. That the systems guide be completed by the committee.

6. That co-operation between customers and competition between manufacturers be stimulated to obtain the best and lightest equipment. It is to be hoped that the CAA will represent the personal aircraft owner in such co-operation.

7. That standards for the writing of specifications to insure completeness be prepared by the customer group or by the committee.

8. That the customer group standardize mounting, space, and circuit arrangements of as many items of electric apparatus as possible. It is recommended further that such standards be published under the auspices of the Society of Automotive Engineers.

9. That a limit on radio noise and method of measurement be prepared by the customer group.

10. That the committee lend impetus to the preparation of training manuals.

Reference to the committee is made in the foregoing recommendations. This refers to the committee on air transportation or a subcommittee thereof. It is contemplated that the best abilities of the equipment manufacturers, the airframe manufacturers, and the customers will be represented on such a committee. They can set standards, prepare specification requirements, and establish a performance code, representing the combined experience of the aircraft industry which will do much to anticipate and prevent electrical failures. Such self-regulation always has been far better than governmental regulation.

DATA

The failures which can occur in aircraft electric systems can be defined into four types by location: source, load center, circuits, and apparatus, plus hydraulic. When a source of power fails, it must be possible to transfer from that source simply and quickly, whether such transfer is accomplished manually or automatically. Correction of a failure at a load center emphasizes reliability or continuity of service. Sectionalized feeder circuits probably will contribute much to such continuity.

Correction of a failure in an individual circuit or piece of apparatus is not easy. The obvious solution by means of a standby unit is impractical because the weight penalty would be severe. An exception has been made in the case of landing gear retractors where electric or mechanical standby units have been used.

Failures of the hydraulic system are a hazard when they occur near electric units if the fluid is inflammable. Much work has been done towards the development of silicone fluids which will not support combustion and which have better temperature characteristics than the previously used hydraulic oils.

A type of failure or near failure which must be considered is one which produces smoke or fire. Experience has shown the odor of burning insulation followed by smoke can produce near hysteria in a flight crew. Faults should be cleared before smoke can develop.

Problems of protection received much attention during the conference and it seemed evident that while solutions were available for all recognized problems, advantage was not always being taken of such solutions. The five objectives of protection were summarized as follows:

1. Interrupt a fault before damage can occur.
2. Isolate a conductor before smoke is emitted.
3. Open circuits to equipment before the latter is damaged.
4. Isolate a fault so quickly that system voltage disturbance is minimized.
5. Isolate a source of overvoltage.

There was some opinion that the ideal protective system could not be obtained. The ideal would permit the carrying of a sustained overload in time of need without loss of service when faults occur. The attainment of the ideal protection system will be tempered by the need of economy in weight. However, one estimate of 25 pounds for a 25-kw system indicated that the weight penalty would not be as severe as many earlier estimates. Further, much of this weight would be neutralized by the higher utilization factor of power sources, and lighter design of power consuming apparatus.

Desirable characteristics of protective devices were summarized as follows:

1. Normal transients should not trip the device.
2. Operation of one should not cause operation of another.
3. Time of operation should be short enough to limit damage.
4. Attention of the crew should be drawn to a tripped device.
5. Re-establishment of service should be simple and easy.

Failure to obtain all the desired and needed characteristics in the protective device sometimes leads to duplication of effort. As an example, the inability of reverse current relays to protect generator circuits properly forced the development and use of an additional circuit breaker. Similarly, the use of nontrip-free circuit breakers can be blamed on the inability to produce completely satisfactory trip-free circuit breakers, or on the unwillingness of the aviation industry to pay the price for its development.

Devices and their integration for the production of the newly developed a-c system for aircraft were described. By utilizing past experience with industrial and aircraft systems, a comprehensive and promising series of protective devices have been developed.

At least one problem of degree remains and that concerns the protection of cable to avoid odor and smoke. There is much variation in cable types, and much data remains to be accumulated on the current carrying capacity of cable in various installations.

The fact that fullest advantage has not been taken of work thus far completed on protective methods and devices can be blamed on the customer group. This group must evaluate the extent of protection which is needed, make a choice of methods, specify devices, and request the installation of complete protection in the airplanes. The electrical engineer in the plant of the airframe manufacturer cannot install complete protection in a new design, however slight the weight penalty, without the backing of the customer's specification.

The importance of system characteristics and limitations has not been appreciated by the aircraft electrical engineer. There have been many examples of electric power supplies which could not meet transient demands of the loads of ground operation. Attempts to provide safety with duplicate services have been foiled by the use of a single control at a point in both circuits. Characteristics of relays, voltage regulators, and generators have not been controlled, and undesirable conditions of resonance could occur. Faults which would not be serious have pulled the system voltage below the recovery limit because a protective device required too much time. The foregoing are only a few examples of system problems, but they indicate the range of responsibility.

Only the airframe manufacturer's electrical engineer is in a position to control system integration, as he is the only one who knows the final circuits of the airplane in time to study system problems before it is too late to do anything about them. The customer group can provide some able assistance particularly when that group specifies and procures some of the apparatus which will be used. It is recommended that the committee help both groups by setting up system design criteria and standards in the guide.

One of the hard-earned lessons of the war was the necessity of designing for environmental operating conditions. Apparatus manufacturers are prone to avoid these design limitations with the excuse that they no longer are needed. However, environment is not concerned with war or peace. Ice is a constant enemy in northern regions and has prevented the operation at crucial times of many types of switches and lighting equipment. Altitude lessens cooling effectiveness and voltage breakdown gradients. Moisture is more dangerous electrically than the fungi which it fosters. Customers' and airframe manufacturers' specifications must continue to require designs which can survive environmental conditions to which the airplane will be subjected. It is admitted that there will be several degrees of environment. A personal airplane will not be called on to operate at the same altitudes as a transport, and neither will face the extremes of the future guided missile. It is recommended that the committee set up standards of environmental conditions.

Reduction in weight has worried designers more than it should. Excess weight handicaps the airplane and is to be avoided. On the other hand, there must be enough weight in a piece of equipment to insure reliability. It is the responsibility of the customer group to resolve this dilemma. The customer specification must state clearly all requirements and provide adequate tests therefor. Then, competitive bidding and manufacturing can be used to obtain a satisfactory article that is light in weight. The ultimate in weight and cost will be achieved only with the assistance of competition.

Of major electric items, the voltage regulator received most criticism. Past designs will not retain their adjustment, they are maladjusted too easily by the crew, they do not feel safe, and maintenance is difficult. Progress is overcoming these objections also was reported, but it was evident that further development was needed.

Limit switches also received criticism. As they are used in exposed locations, resistance to environment is very important. Responsibility for failures also lie with the airframe manufacturer inasmuch as in many instances trouble was experienced with linkage mechanisms.

Warning systems which fail and give false warnings were ridiculed caustically. An important offender is the fire warning circuit, as a signal from this source requires that the engine in question be shut down, the propeller feathered, and other emergency measures taken. This does not cause immediate hazard, but the increased fuel consumption by remaining engines may shorten the aircraft's range until there is danger that the destination cannot be reached.

Complicated designs were criticized, perhaps unfairly. Electronic circuits appear to be complicated, and yet they can give longer trouble-free service than can many simple mechanisms—such as switches. New types of automatic pilots are electronic, and they can do many more things than could the previous mechanical types. Fear of complicated designs should not void the opportunities in such equipment.

The need for proper maintenance was noted often during the conference. This is a customer's problem and responsibility. The aviation industry can be very proud of the maintenance methods and standards which have been developed for engines and aircraft. Electric equipment has been overshadowed by the more important mechanical equipment. Suddenly the electric system has become important, and the maintenance problem has become acute. Without doubt this need will be satisfied in excellent fashion. In the meantime, manufacturers of apparatus can make the task easier by considering maintenance in the original design and by preparing maintenance bulletins or handbooks.

Electrical Essay

Fourier Series Representation of Square Top Wave

The square-top curve, *C*, shown in Figure 1*A* is said to be represented by the Fourier series

$$y=\frac{4}{\pi}[\cos\theta-1/3\cos 3\theta+1/5\cos 5\theta-1/7\cos 7\theta\ldots.]$$

Consider the family of curves,

$$S_1;\ y=\frac{4}{\pi}[\cos\theta]$$

$$S_2;\ y=\frac{4}{\pi}[\cos\theta-1/3\cos 3\theta]$$

$$S_3;\ y=\frac{4}{\pi}[\cos\theta-1/3\cos 3\theta+1/5\cos 5\theta]$$

$$S_4;\ y=\frac{4}{\pi}[\cos\theta-1/3\cos 3I+1/5\cos 5\theta-1/7\cos 7\theta]$$

S_1, S_2, S_3, and S_4 are shown in relation to *C* in Figures 1*B*, 1*C*, 1*D*, and 1*E*, respectively.

The family of curves, S_1, S_2, S_3, S_4, approaches as its limit, the square-top curve *C*.

True or *false?* (*Author's answer: False!*)

Answer to Previous Essay

The following is the author's reply to his previously published essay (*EE, Aug '48, p 771*).

The pessimist is wrong. There can be no diamagnetic hysteresis with diamagnetic moment I_d lagging the magnetic field *H*. Such a phenomenon would violate the laws of thermodynamics and permit perpetual motion. Lord Kelvin first pointed this out.

For iron, the loss per cycle is given by

$$W=\int HdB=\int HdH+4\pi\int HdI_m=4\pi\int HdI_m$$

where the integrals are taken round the loop in the counterclockwise sense as indicated. It readily is seen that the last integral is merely the area enclosed by the loop, taken with a positive sign.

However, for a diamagnetic material, with diamagnetic moment *I* lagging *H*, a hysteresis loop would be as shown in Figure 2, so that the integrals in

$$W=\int HdB=\int HdH+4\pi\int HdI_d=4\pi\int HdI_d$$

would be taken in a clockwise sense.

Hence the last integral would equal the area of the loop, but with a negative sign. That is, the loss per cycle would be negative, and energy would be continuously drawn out from the diamagnetic material.

Any imperfection in the diamagnetism will make the

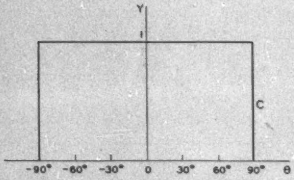

Figure 1A

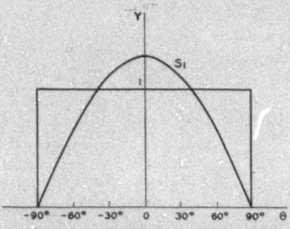

Figure 1B

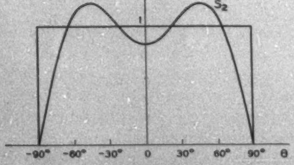

Figure 1C

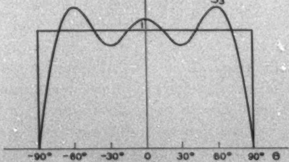

Figure 1D

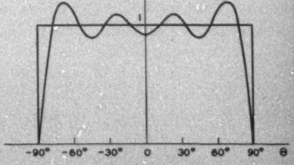

Figure 1E

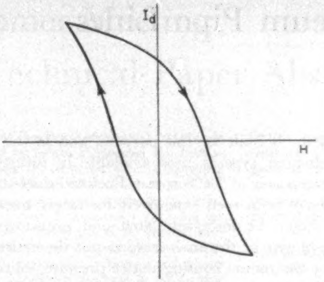

Figure 2

diamagnetic moment lead the magnetic field, not lag it. For example, consider as a model of a diamagnetic material an insulating material with microscopic spheres of conducting material scattered through it.

If the microscopic spheres are perfect conductors, then the induced currents in the spheres always will oppose an impressed field, *H*, and will be in perfect time phase with *H*. If, however, the spheres are imperfect conductors, the circulating currents in the spheres which before lagged the voltage induced round the sphere equator by exactly 90 degrees, now will lag this voltage by less than 90 degrees. Thus the phase of the induced current is advanced and not retarded by imperfection in the conductivity of the spheres.

Imperfection in the diamagnetism therefore, will cause the diamagnetic moment to lead the magnetic field *H*, not lag it. This means that a static diamagnetic hysteresis loop is impossible.

J. SLEPIAN (F' 27)

(Associate director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Precision Microtiming

United States Navy scientists have developed a novel all-electric camera capable of accurately "magnifying" time four million times. This Zarem camera, invented by Doctor A. M. Zarem, heads the list of a series of ingenious precision time measuring instruments and devices used in photographic "microtime technique" that were announced at the Navy's dedication of the new Michelson Laboratory at the Naval Ordnance Test Station, Inyokern, Calif.

Pointing toward highly increased precision and accuracy, these instruments open a new field of scientific analysis by means of what the Navy calls "synchronized microtime photography." The shutter of the Zarem camera has been operated so fast that light moves a distance of only 10 feet during the time of one exposure. It is being used primarily for the study of certain rapidly changing phenomena which heretofore science has been unable to observe and record accurately.

The Zarem camera is about 25,000 times faster than the fastest motion picture camera commercially available. If moving pictures of a bullet leaving the muzzle of a gun were taken at this rate of 100,000,000 frames per second and projected on a screen at the normal rate, the bullet would appear to require about six hours to travel 25 feet.

The extremely fast shutter time is obtained through the use of an electro-optical Kerr cell, a glass tube filled with nitrobenzene in which a pair of electrodes is immersed. This cell is placed between two polarizing filters crossed so that no light can be transmitted. However, when high voltage is applied to the electrodes in the Kerr cell, the state of the polarization of the polarized light is altered immediately, allowing the light image of the subject being photographed to pass through the camera lens to the film. By controlled timing of the voltage, photographic records with an effective exposure time of 0.01 millionth of a second have been obtained. The primary applications of this technique are to phenomena of ultrashort duration. The entire history of an event under observation may take place in one or a few millionths of a second.

Other types of ultrahigh speed cameras developed by the Navy include one with 76 lenses which is able to take pictures at the rate of 400,000 frames per second. The lenses are arranged in an arc around an 8-sided mirror which revolves at a rated speed of 30,000 rpm. Light from the subject is reflected from the revolving mirror through the arc of lenses to a stationary strip of ordinary 35-millimeter film. Known as the RC-4, this cacra was developed by Doctor I. S. Bowen for the Navy program and it has been highly successful in scientific studies of high explosives and shock waves.

The rotating mirror principle is used in still another type of high speed photographic analysis. Time-resolved spectrograms may now be obtained of instantaneous phenomena such as electric sparks. Typical electric sparks last anywhere from one millionth of a second to 20 times that long and with this method scientists are able to tell at what time during the brief history of the spark various parts of the spectrum are formed.

Similar to the *RC-4* is the *RC-3* camera, which uses the principle of the rotating mirror but contains no shutter. Although it is not a true motion picture camera, but gives only a smear type of photographic record, it has been most valuable in certain studies of Naval Ordnance. Like the other cameras in use by the Navy scientists of Inyokern, this camera is able to photograph only those subjects which can be illuminated brilliantly or are in themselves a brilliant light source.

Other microtime instruments are the shadowgraph and shock channel which photographically record ordinarily invisible shock waves traveling through air or other gases. Work has been done in this field before but the Navy's device has been specially developed for use in new fields of microtime research.

Electrification of Petroleum Pipe Lines

M. A. HYDE
MEMBER AIEE

THE ADVANTAGES of pipe lines for the overland transportation of petroleum and its refined products have been demonstrated thoroughly, with more than 85,000 miles of trunk crude oil and products lines now operating in the United States of America alone, and construction of new lines proceeding at a rate limited only by the availability of pipe. Electric power is used increasingly for pipe line operation, because of its increasing availability and a widening appreciation of its advantages from the standpoints of investment in station equipment, maintenance and attendance costs, reliability, and effectiveness of control.

Constant speed motors can be applied to meet the practical operating requirements of most pipe lines. Most modern lines employ a series of stations each containing pumping units of the centrifugal type, in series connection with by-pass connections. With advantageous choice of unit size it is possible to operate on reduced-capacity steps by shutting down units along the line, so selected as to keep the pressures at the several stations within the prescribed operating limits on the suction and discharge sides. In this procedure it is sometimes advantageous to install one of the pumps at each station so designed as to develop half the pressure put up by each of the remaining units. Even greater flexibility can be obtained by designing one unit per station for operation at variable speed through a hydraulic coupling, or by wound rotor induction motor, with the remaining units operating at constant speed.

Automatic pressure-limit control by throttling valve is useful in compensating for unavoidable deviations of the line from hydraulic balance. A control system commonly employed automatically introduces throttling at the discharge of each station to prevent a rise of the outbound line pressure above the established upper limit, and also introduces throttling to prevent a fall of the station suction pressure below the desired minimum. Such a system is useful also for putting individual pump units into or out of service with minimum pressure disturbance on the line. It is always desirable to operate with as little throttling as practical, because the throttled pressure is a part of the pump input power that is not utilized in the line. Hence it is advantageous to select the pump unit sizes so as to provide reasonably small increments of pump pressure.

While many early crude line installations employed open motors, directly coupled to the pumps, today's preferred practice is to separate such motors from the pump room by a tight partition, with a seal for passage of the motor shaft. The inconvenience of a partition between pumps and motors, and the problems of motor room ventilation, are eliminated by installing motors designed for location in the pump room directly coupled to the pump. The explosionproof motor is built for this purpose, and in the squirrel cage induction type is now available in ratings up to 1,250 horsepower at 3,600 rpm. Enclosed duct-ventilated motors have been used extensively for larger sizes. Such motors should be force-ventilated and pressurized by a separate blower at the air intake, to put the entire system including the motor housing under pressure, causing any leakage to be outward from the duct system. The control should be so arranged that before the pump motor can be started the duct system is purged for a timed interval. An air-flow relay at the discharge end of the duct should stop the motor and prevent its being restarted if air flow fails.

In the application of motor starting equipment one of the chief advantages of the squirrel cage motor is realized, namely simplicity of control. Ultimate simplicity is attained by starting on full line voltage, a possibility that always should be explored when the power service is being planned. Starting conditions are improved if the station capacity is divided into two or more units, an arrangement already shown desirable for flexibility. In instances where power is available only over weak service, capacitors have been used to minimize the lagging component of motor current, both for starting and running conditions.

Motor control usually is installed remote from the pump room or in a separate room maintained nonhazardous by pressurized ventilation. With this arrangement the control is of conventional nonexplosionproof type, which is advantageous from the standpoint of convenient maintenance.

A power distribution layout frequently followed feeds the station bus through a main circuit breaker installed in the transformer substation at a distance of 100 feet or more from the station. Tripping the main circuit breaker clears all circuits on its load side, and for this purpose explosionproof devices are provided inside the station. To avoid interrupting essential loads such as station lighting and control room ventilation, these are served through a tap on the supply side of the main circuit breaker and on this circuit explosionproof equipment is installed throughout the station.

One of the prime advantages of electric power for pipe line pumping is the simplification of operating procedure and reduction of operating personnel through the use of centralized station control. When its possibilities are exploited fully, this includes the grouped location, on a control board, of pushbuttons for starting and stopping all the main pumps, the automatic sequence operation of motorized valves on the suction and discharge of each pump, supervision by indicating light of the position of principal valves, light supervision of critical auxiliaries, also a common audible alarm in combination with individual light identification for each of the various protective devices. The control board usually is installed in conjunction with a gauge panel sealed into a window separating the control room from the pump room.

Digest of paper **48-149**, "Electrification of Petroleum Pipe Lines," recommended by the AIEE chemical, electrochemical, and electrothermal committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Summer Meeting Technical Paper Abstracts

These are abstracts of summer meeting papers for which one-page digests have not been received. Those marked "ACO" were made available at the time of the meeting, in the usual pamphlet preprint form, and will not appear in AIEE TRANSACTIONS. Some copies still may be available (at 30 cents to AIEE members and 60 cents to nonmembers), and requests should be addressed to AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

48-144—ACO—Psychotechnical Methods Employed to Select Personnel for Industries; *David W. Mehl* (*A '45*). This paper deals with the use of well-known and approved psychotechnical methods to determine the fitness of applicants applying for positions in industry and other lines of business by testing them for desirable characteristics. The experience which a telephone company in Mexico has had in conducting these tests with applicants is explained fully and numerous examples given of the various tests employed. Stress is placed upon the satisfactory results obtained by certain tests and the disuse of other tests. The combination of two different methods is explained and its usefulness clarified. The economical feature of the tests is mentioned and how the tests enable the company to choose and pick out desirable applicants from those who have had little or no experience. It is pointed out that results obtained have brought about a far better understanding between employees and management and between the employees themselves.

48-157–ACO—The Intercommunication of the Ericsson and Rotary Automatic Telephone Systems in Mexico City; *Carl E. J. Danielsson* (*A '34*). The two automatic telephone systems of Mexico City, Ericsson and Rotary, functioning independently for many years, were interconnected on January 10, 1948, thus forming a single 100,000-line telephone network. Calls between the two systems, which are of different design, are established automatically with the same ease as a local call, the selection of the desired number, being controlled by means of an auxiliary register, working in parallel with the local register in the exchange where the call is originated.

48-130–ACO—Manufacturing Electric Apparatus in Mexico; *J. V. Schmill* (*A '44*), *R. M. MacGregor* (*M '46*). This paper on the manufacturing of electric apparatus in Mexico points out the need for the establishment of electrical industries to maintain financial prosperity and economic stability in the country. It is estimated that Mexico will produce 50 per cent of all electric apparatus and appliances that are used in the country. Various manufacturing difficulties are described such as altitude which has a direct bearing on the construction of motors, availability of materials, type of market to be supplied, and the over-all labor situation. Lack of standardization of voltage is a drawback to manufacture and sales as, likewise, is the shortage of electric power in many sections. It is pointed out that the limited market in Mexico for certain electric products such as refrigerators does not permit changes of designs and models as frequently as in the United States because of the heavy investment required for tool changes. Extreme shortage of skilled labor will require a comprehensive training program of men who never have seen a machine or the inside of a factory but, due to the average Mexican workman's ability to learn quickly, such a program can be speeded up. Housing and transportation of workmen offer additional problems as many factories are being constructed in far-off outlying districts.

48-146–ACO—The Impacts of Electronics on Engineering Education in the United States; *W. G. Dow* (*M '32*). It is pointed out that electronics is exerting a powerful broadening influence on electrical engineering practice, and therefore a correspondingly broadening impact on the hitherto relatively narrow but intensively treated electrical subject matter of engineering curricula in the United States. The theme of the paper is that breadth must be incorporated without sacrificing the present strength in depth. The broadening impact is extending the study of a-c linear circuitry to include for all students a coverage of all usable frequencies and power levels; it should give a strong place in the curriculum to certain noncircuit studies for electrical engineers, such as radio propagation, heat transfer, quantum mechanics, electron dynamics, and the kinetics of random motions of electric particles. Introduction of the formal study of Maxwell's equations into the undergraduate curriculum is anticipated. Questions are raised as to what is the most useful purpose of the fifth-year offerings, in view of the increase in variety of electrically important subject matter, and of the undesirability of early specialization. Attention is called to the increasing demand for the teaching of more electrical engineering material, and particularly electronics, to nonelectrical engineering students, for instrumentation and control purposes.

48-185–ACO—Electronic System to Control Speed and Tension in Paper Manufacturing Machines; *Angel Rosales de la Mora* (*A '44*). The electronic Amplidyne system speed regulator is very simple compared with any other known before. It is possible to avoid many mechanical complications and to obtain a very simple operation. A master voltage of common reference for all the regulating units has the main purpose of maintaining the constant speed, once this has been selected. The speed of each section is indicated by means of a pilot generator, it is compared with the reference voltage and any difference will increase or decrease the voltage of the motor camp, maintaining it at the desired speed. The amplifier consists of two parts, an electronic preamplifier and an Amplidyne generator as power amplifier. The combination offers the most satisfactory results to obtain fast corrections and avoid complications of mechanisms, giving as a result advantages of great usefulness.

48-147–ACO—International Aspects of Technical Literature; *Edward P. Hamilton.* Since the days of Galileo, the true measure of scientific accomplishment has been in terms of the scientist's net contribution to the physical, intellectual, and spiritual welfare of man. The real philosophy of science has admitted of no purely nationalistic boundaries; and scientists on the whole have been among the most ardent proponents of unrestricted speech and the free communication of their ideas to contemporaries in other lands and on other continents. At the same time, however, and possibly as an accompanying result of the natural tendency for technical men of similar interests to band together in professional groups or societies devoted to the advancement of a particular specialty, certain disturbing evidences of nationalism have crept into the scientific picture. Leaving aside questions of national or continental security, an indication of this unfortunate nationalism, or sectionalism, can be found in the complacency with which many scientists and engineers tend to regard the current state of scientific literature dealing with their own particular specialties.

48-181–ACO—Electric Cables in Mines; *E. W. Davis* (*F '34*). In the early days of mining, electricity was not instrumental in the mining of coal or other minerals, and cables generally were referred to as wire ropes for coupling cars or hoisting cages in shafts and cars on slopes or inclines. Gradually, steam-driven hoists, pumps, and ventilation fans were converted to electric drive; and animal haulage was replaced with trolley locomotives and storage-battery locomotives With the increased speed in transportation afforded by electrically driven haulage equipment, it became necessary to speed up mining operations. Electric transmission cables were extended to the working places, and electrically driven machines were enlisted to drill, cut, and load the product. Today mining is one of the largest industries in the United States and is heavily electrified. Because of the specialized nature of many branches, the electric equipment involved is highly unique. This specialization extends even to the fixed and portable cables used to supply the equipment with electric power. In particular, coal mining has required the development of special electric cables peculiar to this branch of the mining industry and adapted to fit the many machines employed in taking the coal from the seam or vein and bringing it to the surface. The mechanization of coal mines has resulted in a great increase in the amount of mobile mine machinery. Not so many years ago, there were only drills, mining machines, and gathering locomotives at the face. Today, in addition, there are shuttle-cars, loaders, drill trucks, duck bills, and face conveyers—all requiring trailing cables. Much of this equipment is interdependent for continuity of operations, hence the need for the utmost care in the mechanical handling of an extremely important component—the associated electric trailing cables.

48-159-ACO—The Equivalent Circuit and Constants for a Double Squirrel-Cage Rotor Induction Motor; *R. C. Frese (A '45).* The theory and application of double squirrel-cage induction motors, has been discussed extensively in the technical literature by different authors. But very little has been written about a method whereby this theory can be applied, in order to enable the design engineer to calculate the constants and performance of a double squirrel-cage rotor induction motor. This paper is an attempt to develop a simplified method to calculate the motor starting and running constants. A knowledge of these constants permits the calculation of motor performance by any of the usual methods.

48-137-ACO—A Practical Application of Standard Apparatus—Factory-Assembled Substation; *D. E. Craig (A' 45), E. M. Hunter (F'48), L. D. Madsen (M '47).* Adequate planning for growth and consideration of apparatus standards in early planning stages result in all of the recognized economic, installation, and operating advantages inherent in the present and future application of standard factory-assembled substations. The paper's description of standard factory-assembled substations shows:

1. That these substations are made up of items which are built in accordance with industry-wide standards and therefore acceptable from the standpoint of quality, rating, and operating characteristics.
2. There are five standard basic types of primary substations: radial, low-voltage selective, primary network, spot network, and duplex.
3. There are four standard basic types of secondary substations: radial, low-voltage selective, spot network, and low-voltage network.
4. That they may be applied to electrical utility systems or industrial systems.
5. That they may be used to supply power and lighting in industrial plants or auxiliary power in generating stations.
6. That they may be installed indoors or outdoors.
7. That the few simple, standardized components may be combined to provide a large variety of substations.
8. That adherence to these existing standards facilitates system planning, procurement, and installation of substation equipment.

The use of equipment which has been proved by many years of operation under many conditions is a logical substitute for many months of planning and study by skillful engineers. The use of equipment manufactured in accordance with well-established industry standards simplifies all of the steps necessary to put an electric system into successful operation and keep it operating at a minimum of expense in time and money in initial cost, upkeep, and future expansion.

48-183-ACO—Safety Codes as American Standards; *W. R. Smith (F '30).* The goal toward which those who co-operate in standardization work set their faces is not reached when standards are completed and approved. It is the use of the standards that is the end desired and only through utilization and the endorsement that thus is evidenced will the real purposes behind the effort be accomplished. This is especially true of safety standards and calls for the development, in the minds of those concerned, of a willingness to accept the standards that are established and then go forward from there. Such standards are not static and can be changed as experience demonstrates the respects in which they are inadequate or have gone too far in their requirements. As the effort goes forth to eliminate trade barriers and promote an ever-increasing flow of commerce between all nations of the earth and especially between the countries of our western hemisphere, we must be ever conscious of the contribution of safety standards. Safety standards are the means by which the experiences of one generation, or of an industry, can be made to serve those who come after and who thus may be saved the necessity of proving for themselves through their own individual experiences the correctness of the safety provisions concerned with designs or practices and procedures. In relations between an industrial enterprise and governmental agencies and between plant management and labor, safety standards can be of inestimable value in providing the means for the solution of many problems that otherwise might be difficult. Much of that which results in controversies before courts and commissions is concerned with what is intended in words and phrases and safety standards represent agreement, in advance, on definitions and requirements, so that those hazards to be overcome by safety features in machinery or in practices of use and operation are defined in terms that have been accepted by qualified representatives of all interested groups. May it not, therefore, be anticipated that as the true significance of these safety standards becomes more generally understood, and the benefits in every way realized by all concerned, then will those who have labored to establish the standards feel that their work has not been in vain. To all who have contributed in any way, will come that satisfaction which is enjoyed only by those who through the exercise of sound judgment, have selected and placed in the hands of workers in all fields those tools which are best suited to their tasks.

48-142-ACO—The Textile Industry in Mexico; *Aurelio Lobato.* Problems of the cotton textile industry in Mexico are dealt with and it is pointed out that a poor quality of fabric is manufactured because of the low purchasing power of workmen and small farmers who constitute the largest number of consumers of cotton goods. As a consequence, modernization of the industry has been slowed up and hand labor has caused production costs to be high. Labor contracts which at one time served their purpose and permitted harmonious management-labor relations as well as continuous uniform output by the mills are today inadequate as a result of opposition by workers to installation of modern equipment which cuts down number of operators and introduction of new systems which further lessens employment of ordinary labor. Comparisons are made of labor output in the textile industries of the United States, England, and Mexico. Revision of the old labor contract to enable the textile industry to be modernized now is being done inasmuch as labor and the government have agreed that such a revision is required. It is anticipated that it will take ten years to modernize the textile industry in Mexico at a cost of 40 million dollars to which must be added 30 million dollars to purchase 5,000 new looms to take care of the future consumer demand. All financing will be effected in Mexico.

48-154-ACO—Comments on the Development of Modern Power System Design Concepts and Operating Practices; *D. M. Jones (A '21).* Electric Power is the basis of our industrial age. This industrial age already has produced the highest living standards. Thus there is a basic urge on the part of society to continue this industrial era. Out of this has developed the rising general demand for electric power. This demand dictates a sustained development of power systems. This development is leading to a basic power system design and operating pattern with both practical and economic advantages, and has reached a stage where trial and error have been superseded by precise analysis. Therefore there is now little excuse for random departures from this basic trend in system design, especially when it is realized that such departures will carry economic penalties. With the power system pattern thus crystallized, the rising demand for power ahead can be met with understanding and assurance.

48-118—Trends and Practices in Modern Industrial Power-Distribution Systems; *W. C. Bloomquist (M '45).* As suggested by the title, this paper describes and summarizes some of the important factors for a modern industrial power-distribution system including selection of voltage, distribution methods, circuit arrangement for varying degrees of service reliability, capacitor applications, system grounding, safety, and the over-all economic importance of factory-assembled unit-type equipment. The selection of system voltage and how voltage level is influenced by economic consideration is well covered. Included is a useful chart showing preferred voltages for main power distribution and generation in terms of plant electrical capacity. The load-center method of power distribution—its principles, economic advantages, and applications—is summarized briefly. The importance of the reliability of the electric system from the management viewpoint is introduced. The more common circuit arrangements for enhancing the system reliability are shown and described briefly. The operating advantages of grounded operation for the main power-distribution system are covered. The trend is definitely toward this type of operation. Attention is called to the importance of properly engineering the plant protective grounding system in the interest of safety to personnel. Data are included showing the electric system capacity released by power-factor improvement and the economic limits of capacitors for this purpose. The advantages of factory-assembled unit-type equipment and the economic advantages of standardized equipments from both the user's and manufacturer's viewpoint are well summarized.

INSTITUTE ACTIVITIES

We Begin a New Institute Year —A Message From the President

Everett S. Lee

Together we begin a new Institute year—a year in which each of us advances his contributions of the past year into the year at hand for great mutual good.

For each member everywhere there is work to be done, enjoyable work, together with your associates to continue the engineering friendships which you have established and to make new ones, and to progress the activities with which you are associated, be they Section, Student Branch, technical committee, general committee, or officer at Student Branch, Section, District, or national level.

Our far-reaching activities covering all electrical engineering have been well established and their interest has been vigorously maintained and advanced. There may be some members, however, who do not feel that they are sufficiently established within the Institute to have caught its full spirit, to have appreciated its vast contributions, to have made the Institute life a vital part of their engineering life, who have not had the pleasure of Institute engineering friendships. To these I suggest a definite budget of time for Section activities, meeting and joining with their associates to progress the planned activities and to join in the planning of whatever is together thought to be mutually helpful, ever mindful of the opportunity awaiting participation, which means the giving of time and talents to the progression of the desired work. This is the formula of those who have gone before; this is the formula for us now.

And as opportunity advances to join in the District and national activities, the enjoyment and satisfactions become the greater. And for the Students, a full participation in the Student Branch activities is the forerunner of all of these. There is a place for every member and a work for every member to do if he but will.

Especially to the Student members who just have been graduated from their engineering schools and who are continuing their electrical engineering activities, do I urge that you enter the Section activities of the Institute in your community where you are—making yourselves known to the officers, and bringing to the Section your abilities for continued participation. And the Section members and officers welcome you to this further participation.

Our national problems are not many. We are not quite balancing our budget. Each member has received the chart of income and expenditures. We will have to act on this problem during the year. Expenditures have been scrutinized carefully. Increased costs have affected us as well as all others. As I am privileged to talk with more and more of our members, I find they do not want our opportunities for further participation to be jeopardized. They are proud of our standing as a profession. They want continued participation, and express a willingness to sustain it, even at increased cost.

Everywhere I go I find the members asking as to the over-all engineering society. The activities in our Institute on this subject in the past two years resulted in a report; this has been referred to Engineers Joint Council. There it still is.

But I would call definitely to your careful attention the opportunities we have for participation to bring to engineers the recognition which engineers see in their brother professions of the law and of medicine. I call to your attention that there is a doctor in the intimate talk in every family circle of our land; there is a lawyer in the intimate talk of nearly every family circle of our land; whereas the engineer, while bringing contributions to every family in our land through his daily activities to bring into being every material thing we have, is not personally in the intimate talk of every family circle of our land. The engineer in his contributions is a man apart—his contributions are the thing—not the engineer as an individual.

Now the engineer can change this if he will participate the more in the personal aspects of our life. We are told today the education facilities in every community in our land need added aid. Through committee and school participation engineers can be of service here, and as the service is personal, the engineer becomes known, and engineers will become known for their service. This is only one of many opportunities. They abound in the service clubs, in civic programs, in the churches. Through an augmentation of personal participation in these services, recognition of the engineer will become established. This is not new. It is going on and has been for years. But there needs be more, and it needs to be made more personal. I trust that in each Section the program committees, as they plan their Section meetings for the year, include a meeting wherein the member participation in community affairs be the subject. And may it be thoughtful. Let it be an experience meeting, just as our technical meetings are experience meetings. And let it be the beginning of many more to come. And if perchance there are no experiences to relate, let that situation be studied and analyzed to answer the question, "Why?" And I am sure the results will be for great good.

Everett S. Lee

We will not stop in our efforts for an over-all engineering society; however, personal engineering recognition which many engineers feel they should have will not come from the top alone. It can come only if there is the personal knowledge of engineers and their contribution at the individual level in the community. This each engineer has to bring about himself. The whole then will emanate as a totality, ever enlarging from the local participation to the over-all. To those engineers who may not feel this way, I offer the foregoing for consideration and thought and action.

In the last analysis, the world needs engineers for engineering, and it needs electrical engineers for electrical engineering. To this need we apply ourselves. The efforts we put into the more general activities to bring to our fellowmen a more personal knowledge of the engineer is the frosting of the cake. We have baked a good cake. And if we want it frosted, we will have to frost it.

Middle Eastern District to Meet in Washington, D. C., October 5–7

A technical program of exceptional interest has been planned for the 3-day meeting of the Middle Eastern District to be held in Washington, D. C., October 5–7, 1948. Headquarters will be in the Statler Hotel with registration beginning Monday afternoon, October 4. A general session will be held at 10:30 a.m. Tuesday, with Doctor E. U. Condon, director of the National Bureau of Standards, as the principal speaker. The air transportation committee has selected this meeting for its principal technical sessions on air transportation for the year, and aircraft electrical engineers should find many papers of interest. Four technical sessions covering marine transportation are scheduled and will afford an unusual opportunity for marine electrical engineers in manufacturing, shipbuilding, and the government agencies to meet for the discussion of a diversified group of marine electrical subjects. Inspection trips of unusual interest, entertainment for the women, a smoker, and a dinner-dance assure a busy time for everyone.

INSPECTION TRIPS

An inspection trip to the David Taylor Model Basin Research Laboratory has been planned for Wednesday afternoon. Thursday morning the Carnegie Institution of Washington will be the center of interest. Thursday afternoon two trips are scheduled, one to the Washington National Airport, the other to the National Bureau of Standards.

ENTERTAINMENT

A smoker will be held on Tuesday evening and a banquet followed by dancing on Wednesday evening. Golf and tennis will be arranged for as requested. The women's program includes an informal supper-game party while the smoker is in progress. A sight-seeing trip to Mt. Vernon with luncheon at Collingwood Inn has been planned for Wednesday. Thursday has been set aside for sight-seeing and shopping in Washington proper.

HOTELS

Meeting headquarters will be in the Statler Hotel which is within two blocks of the Carlton, Hamilton, Hay Adams, and Lee Sheraton Hotels. Members of the District receiving an "Application for Hotel Accommodations" form should fill in and mail it promptly to the hotel of their choice. Confirmation will be made directly by the hotel accepting the reservation.

Rates are as follows:

	Single	Twin Beds
Statler	$4.50–$11.00	$9.00–$13.50
Carlton	6.00– 8.00	9.00– 11.00
Hamilton	4.50– 5.00	7.00– 8.00
Hay Adams	4.50– 7.00	8.00– 9.50
Lee Sheraton	4.50– 6.00	7.00– 9.00

ADVANCE REGISTRATION

Members of the District who will be sent advance registration cards should fill them out as soon as possible and forward them to J. O. Pease, Chairman, Registration and Housing Committee, Rumsey Electric Company, 219 Southern Building, Washington 5, D. C. Prompt action greatly will assist the committees making arrangements for the meeting and save time upon arrival. A registration fee of $2 will be charged all nonmembers, except Enrolled Students and the immediate families of members.

DISTRICT MEETING COMMITTEE

Members of the District meeting committee are as follows:

William McClellan, *honorary chairman;* Fischer Black, *general chairman;* W. F. Dietz, *arrangements;* D. K. Steidinger, *secretary-treasurer;* D. S. Bender, *technical meetings;* J. S. Antel, *students;* R. D. Bennett, *special meetings;* L. H. Cleary, *finance;* I. F. Conrad, *publicity;* F. B. Crider, *smoker;* C. H. Giroux, *sports;* Mrs. W. J. Lank, *ladies;* W. J. Lank, *entertainment;* D. Lewis, *dinner;* J. O. Pease, *registration;* G. R. Wilhelm, *inspection trips.*

Tentative Technical Program

Middle Eastern District Meeting, Washington, D. C., October 5–7, 1948

Tuesday, October 5

2:00 p.m. Air Transportation

CP.* Captain A. H. Bergeson, United States Navy, Bureau of Aeronautics

48-213. Analysis and Redesign of a Carbon Pile Voltage Regulator for Aircraft Generators. *W. B. Kouwenhoven, G. J. Thaler*, Johns Hopkins University

48-214–ACO. Aircraft Carbon-Pile Voltage Regulators, Fundamentals and Design Improvements.** *B. O. Austin, H. H. C. Richards*, Westinghouse Electric Corporation

CP.* Personnel Safety in Aircraft High-Voltage Electric Systems. *M. H. Adolphe*, Lockheed Aircraft Corporation

2:00 p.m. Power

48-212. The True Dielectric Breakdown Strength of Electric Cable Insulating Papers. *Paul Cloke, Burt Bates*, University of Maine

48-216. An Experimental Investigation of the Electrical Performance of Bolted Aluminum to Copper Connections. *W. F. Bonwitt*, Burndy Engineering Company, Inc.

2:00 p.m. Electric Instruments

48-217. Naval Ordnance Laboratory 6-Trace Cathode-Ray Oscillograph. *P. L. Edwards*, Naval Ordnance Laboratory

48-218–ACO. A Precision Electrothermic Voltmeter for Measurements between 20 and 20,000 Cycles Per Second.** *F. L. Hermach*, National Bureau of Standards

48-219. Performance of Portable Electric Instruments in Magnetic Fields. *A. E. Peterson*, National Bureau of Standards

CP.* Effects of Harmonics on Watt-hour Meter Registration *A. G. Ennis*, John Hopkins University Applied Physics Laboratory

2:00 p.m. Marine Transportation

48-220. Silicone Insulation in Submarines—Toxicity. *H. P. Walker*, Bureau of Ships, United States Navy Department; *Lieutenant Commander T. E. Shea*, Naval Medical Research Institute

48-221. Functional Evaluation of Insulating Materials. *K. N. Mathes*, General Electric Company

48-222. Magnetic Amplifiers for Naval Shipboard Applications. *L. W. Buechler*, Bureau of Ships, United States Navy Department

Wednesday, October 6

9:00 a.m. Air Transportation

48.215–ACO. Sensitive Relay Contact Protection Systems.** *J. P. Dallas, T. H. McCully*, Hughes Aircraft Company

48-203–ACO. Protection of the Airplane Main Bus. *D. W. Exner*, Boeing Airplane Company

48-223. Proposed Circuit for Aircraft Reverse-Current Cutout. *J. M. Marzolf*, Naval Research Laboratory

48-224. A Polarized Relay as an Aircraft Control Element. *R. E. Johnson, F. A. Glassow*, Barber Coleman Company. Demonstration

9:00 a.m. Illumination Joint Session Illuminating Engineering Society-AIEE

CP.* Sources for Projection Equipment. *J. A. Bartelt*, Engineer Research and Development Laboratories, Fort Belvoir

CP.* Modulated Light Sources. *W. S. Huxford*, Northwestern University

CP.* Atmospheric Transmissometry. *C. A. Douglas*, National Bureau of Standards

CP.* Lamp Progress and Development in 1948. *Alston Rodgers*, General Electric Company, Nela Park

9:00 a.m. Naval Testing

CP.* The Design of an Instrument Servomechanism to Be Used on a Recording Ship Model Dynamometer. *Henry Carleton*, David Taylor Model Basin

CP.* Safety Control Features of Towing Dynamometers at the David Taylor Model Basin. *L. G. Lehman*, David Taylor Model Basin.

CP.* The Electrical Design Features and Prediction of the Performance of the Navy's New 12-Motor High-Speed Towing Dynamometer. *S. E. Dawson* David Taylor Model Basin

9:00 a.m. Nuclear Engineering

CP.* Survey of Radiation Measurement Methods. *G. W. Dunlap*

CP.* Power from Piles. *Farrington Daniels* or *Clark Goodman*

CP.* Relative Comparison of Various Types of Accelerators. *Stanley Livingston*

CP.* Instrumentation and Techniques of Protection from Radiation Injuries. *K. Z. Morgan*

9:00 a.m. Marine Transportation

48-225. Selective Tripping Arrangements for Protection of Ships' A-C Electric Distribution Systems. *J. R. Cole*, Bureau of Ships, United States Navy Department

CP.* Development of Selective Tripping of Low-Voltage Air Circuit Breakers. *William Deans*, I-T-E Circuit Breaker Company

48-227. Shipboard Degaussing Installations for Protection Against Magnetic Mines. *N. B. Michel*, Bureau of Ships, United States Navy Department

Middle Eastern District Meeting Program (Continued)

48-228. Compensation of Effects of Degaussing Coils on Shipboard Magnetic Compasses by Use of Compass Compensating Coils. *R. A. Robinson*, Bureau of Ships, United States Navy Department

2:00 p.m. Air Transportation

48-243–ACO. A 24,000-RPM Alternator for Aircraft.** *T. J. Martin*, Jack and Heintz Precision Industries, Inc.

48-250. Steady-State Analysis of Aircraft D-C Generators. *Earnest Van Valkenburg*, *Whitney Matthews*, Naval Research Laboratory

48-230–ACO. Electrical Prerotation of Landing Gear Wheels.** *J. H. Keyser, Jr.*, formerly with the Lockheed Aircraft Corporation

CP.* Aircraft Cockpit, and Instrument Lighting. *J. M. Roper*, Bureau of Aeronautics. Demonstration

2:00 p.m. Power

48-211. Effects of Silicone Vapor on Brush Wear. *J. Marsden*, *R. H. Savage*, General Electric Company

48-231. Use of Propulsion Generators on Naval Vessels to Supply Shore Power. *F. E. Anderson*, *W. H. Fifer*, Bureau of Ships, United States Navy Department

CP.* Use of Power in Connection with Floating Dry Docks. *W. W. Newland*

48-232. Origin of the Electric Motor. *Joseph Michalowicz*, Catholic Univesity of America

2:00 p.m. Communications

CP.* Military Meteorological Communication. Major *J. M. Van Arsdell*, United States Army

CP.* Multipoint Networks for Telephone and Telephotographic Services. *E. Nichols*, American Telephone and Telegraph Company

48-233. Facsimile Transmission for Pickup and Delivery of Telegrams. *G. H. Ridings*, Western Union

2:00 p.m. Electrical Engineering Developments

48-234. Automatic Standing Wave Indicator. *P. J. Allen*, Naval Research Laboratory

48-235–ACO. Some Characteristics of the Human Servo.** *F. V. Taylor*, Naval Research Laboratory

48-236. Recent Research on Pulsed Light Sources *B. R. Whalen*, Naval Ordnance Laboratory

48-237–ACO. External Magnetic Field Patterns Surrounding Minute Portions of Recording Wires.** *I. L. Cooter*, National Bureau of Standards

48-238. The Magnetic Fluid Clutch. *Jacob Rabinow*, National Bureau of Standards

Thursday, October 7

9:00 a.m. Air Transportation

48-229–ACO. A Rectified A-C Electric System for Aircraft.** *L. M. Cobb*, *W. L. Kenshaw*, *O. E. Erlandson* The Glenn L. Martin Company

—PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in five-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the technical program committee ultimately will be published in PROCEEDINGS and TRANSACTIONS; also, each is scheduled to be published in ELECTRICAL ENGINEERING in digest or other form.

48-239. Starter-Generator Control System for a Multijet Engine Airplane. *Victor Hart*, Boeing Airplane Company

CP.* Lockheed, "Constitution," Electrical Test Program. *H. F. Rempt*, Lockheed Aircraft Corporation

48-240. Ground Power for Aircraft. *J. H. Blankenbuehler*, Hobart Brothers Company, and the Motor Generator Corporation of Troy, Ohio

9:00 a.m. Rural Electrification

48-241. Rural Distribution Voltages. *W. M. Edmunds*, *G. B. Roloson*, Rural Electrification Administration

48-242–ACO. Inductive Co-ordination Practices.** *M. W. Rothplatz*, *H. S. Williams*, Rural Electrification Administration

9:00 a.m. Communication. Joint Session URSI(International Scientific Radio Union) –IRE (Institute of Radio Engineers)–AIEE

CP.* A Report on the New York-Boston Radio Relay System. *C. A. Borgeson*, American Telephone and Telegraph Company

CP.* Washington Television Installations of NBC. *Donald Cooper*, National Broadcasting Company

CP.* Progress in Air Transport Radar. *Lieutenant Commander E. W. Harrison*, United States Navy Department

CP.* A paper on the general topic of "Electronic Heating" by a speaker from the Westinghouse Electric Corporation

9:00 a.m. Marine Transportation

CP.* Magnetic Minesweeping Systems. *J. F. Condon*, *H. M. Koslow*, Bureau of Ships

48-226. Ventilation of Rotating Electric Equipment on Shipboard. *A. M. Harrison*, Westinghouse Electric Corporation

48-244. Electric Propulsion in Naval Surface Vessels. *N. T. Jucarone*, Bureau of Ships

2:00 p.m. Naval Testing

CP.* The Development of Instruments to Measure Performance of the Navy's New 8-Inch Rapid Fire Gun. *Edward Wenk, Jr.*, David Taylor Model Basin

CP.* The Design of Lightweight Velocity Meters for Measuring High Shock. *G. C. Riggle*, David Taylor Model Basin

CP.* A Measurement System for the Determination of Minute Charges in Capacitance. *G. W. Cook*, David Taylor Model Basin

CP.* Instrumentation for and the Conduct of Full-Scale Trials of Naval Vessels. *W. R. Romaine*, David Taylor Model Basin

2:00 p.m. Government Relations

Address: **Supervisory Aspects of Government.** *Percy H. Thomas*, Federal Power Commission

Address: **Discussion on Development of Electric Power by Government.** *H. J. McPhail*, Bureau of Reclamation

Address: **Government in Relation to Communications.** *E. W. Allen*, Federal Communications Commission

2:00 p.m. Marine Transportation

48-245. Overload Protection for Silicone-Insulated Motors for Shipboard Use. *J. C. Grigg*, *J. E. Watkins*, Bureau of Ships

CP.* Improving Internal Lighting in United States Naval Vessels. *E. Boghosian*, Bureau of Ships

48-246. Effective Resistance and Inductance of 3-Conductor Shipboard Power Cables. *S. D. Summers*, Naval Research Laboratories.

Discussion of proposed revisions to Section 45 of AIEE Standards (Electrical Installations on Shipboard). To be led by members of AIEE committee on marine transportation

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*CP Conference paper; no advance copies are available; not intended for publication in *TRANSACTIONS*

**ACO. Advance copies only available; not intended for publication in AIEE *TRANSACTIONS*.

1948 Midwest General Meeting to Be Held in Milwaukee, Wis.

Colorful fall, Wisconsin's most beautiful and most famous season, awaits AIEE members attending the Midwest general meeting in Milwaukee, October 18–22, 1948.

The beautiful scenery may be seen to advantage in Wisconsin's many state parks, reported to be among the finest in the United States. Within a day's traveling time of Milwaukee are dozens of parks, each featuring its own private type of natural setting, yet having the same, complete facilities that make a picnic or hike so enjoyable, and AIEE members are warned to bring cameras loaded with Kodachrome film.

Within the city limits of Milwaukee is Mitchell Park nationally known for its sunken gardens and botanical conservatory where flower shows are held the year around. A few miles to the south is Grant Park, with its steep bluffs, expansive beaches, green golf course, tennis courts, and miles of hiking trails through the woods. Inland from Grant Park is Whitnall Park, with acres and acres of rolling green grass, carefully tended flower gardens, and big trees.

Sixty miles north of Milwaukee is Terry Andrae State Park, which is also on Lake Michigan and has a wide variety of trees that turn into a kaleidoscope of color in the fall, and within an easy day's drive of the AIEE meeting headquarters is Devil's Lake State Park where ice-age rocks blocked off a river and left a deep lake. Nearby Derward Glenn offers an interesting study in geology. Other state parks, Potawatomi, Penninsula, Kettle Moraine, Tower Hill, plus dozens of state and national forests also are within easy driving range of the AIEE meeting headquarters in Milwaukee. Automobiles may be rented in Milwaukee, and the AIEE meeting staff will be glad to assist visiting members with arrangements.

TECHNICAL PROGRAM

Plans for the technical program for the Midwest general meeting are shaping up very nicely. At present 33 sessions, each session comprising the customary three to four papers, are planned on the following subjects:

Power generation
Substations
Relays
System engineering
Carrier current
Switchgear
Transformers
Insulated conductors
Mining and metal industry
General industry applications
Industrial power systems
Industrial control
Electric heating
Basic science
Communications
Instrument and measurements
Land transportation
Domestic and commercial applications
Education

Milwaukee engineers will be well represented on the program, since the electrical industries of Milwaukee have gone all out in support of the effort to make this a memorable meeting. It will be remembered that the Midwest general meeting is an innovation introduced last year, Chicago being the host for the first meeting. With the introduction of this meeting, the number of full-fledged meetings was brought up to four per year, namely, the winter meeting, the Pacific Coast meeting, the summer meeting, and the Midwest meeting, and judging from the demand for sessions, and the number of papers offered, the addition of this meeting certainly seems to have been justified.

INSPECTION TRIPS

Among the inspection trips planned for the Midwest general meeting are the following:

1. Globe-Union Company—production of storage batteries, automotive spark plugs, steatitic ceramics, pocket-size transmitting and receiving radio sets

2. Allen-Bradley Company—motor controls

3. Cutler-Hammer, Inc.—control equipment

4. Harnischfeger Corporation—manufacture and assembly of overhead traveling cranes, demonstration of an actual crane equipped with a magnetorque control, also assembly of electric power shovels, motors, brakes, and electric welding machines

5. Line Material Company—short-circuit testing laboratory for the testing and development of electric distribution apparatus in the primary voltage range of 2,400 to 69,000 volts

6. Blatz Brewing Company—bottling plant and guest auditorium

7. Joseph Schlitz Brewing Company—largest single establishment in the United States devoted exclusively to the brewing of beer

8. Pabst Brewing Company—founded in 1844

9. A. O. Smith Corporation—tour including visits to semiautomatic frame plant, pipe mill, vessel shop, laboratories, and exhibit hall, followed by discussion period

10. Square D Company—manufacture of products of the industrial controller division including automatic motor starters, resistance welder controls, heavy duty d-c controls for steel mill use, and automatic pressure switches

11. Allis-Chalmers Manufacturing Company—farm tractors, hydraulic turbines and generators, steam turbine-generator equipment, transformers, unit substations, switchgear, voltage regulators, and so forth

ENTERTAINMENT

The following events have been planned for the entertainment of AIEE members attending the Midwest meeting:

Tuesday, October 19, 6:30 p.m.—Stag smoker, dinner (500 limit), and entertainment, Hotel Pfister, $4.

Wednesday, October 20, 6:30 p.m—banquet and dance, informal (400 limit), Hotel Schroeder, $4.

Thursday, October 21, 7:30 p.m.—Milwaukee Gemuetlichkeit (650–1,000), Lynde Hall, Allen-Bradley Company, basketball games, Industrial League teams, games, cards, refreshments

Reservations for the men's smoker and the dinner-dance will be on the basis of cash in advance through the mail with a small block of tickets reserved for late comers.

SPORTS

Golf enthusiasts will have an opportunity to have lunch followed by an afternoon of golf on Tuesday, October 19, at the North Hills Country Club. This club, embracing a well-groomed 18-hole golf course, is situated about 15 miles northwest of Milwaukee on highway U. S. 41. It is a picturesque and interesting par 72 wooded layout nestled in gentle rolling terrain. The beauty of this 6,288 yard course is enhanced further as the Menomonee River winds its way across the grounds and contributes largely in the creation of some very unusual golf holes. Each nine holes is virtually horseshoe-shaped with the incoming nine encircling the other, and its unique arrangement affords play at any time in the afternoon without encountering the sun's blinding rays.

North Hills' imposing clubhouse has been greatly enlarged and remodeled this year and offers to guests many modern facilities. Here good food, refreshments, and comfort may be enjoyed while viewing the golf course through its facade of many picture windows in a setting unequalled in this area. An afternoon in this genial and pastoral atmosphere should not be overlooked by golf enthusiasts.

WOMENS' PROGRAM

A well-planned program has been arranged by the women's committee to assure all women attending the Meeting a pleasant and interesting stay in Milwaukee. The program schedule is as follows:

Monday, October 18
"Get-Acquainted Day." Hostess parlor open
Tea will be served during the afternoon
Monday evening, wives join husbands for brewery trips

Tuesday, October 19
Tour of Phoenix Hosiery Company at 9:00 a.m.
Tuesday afternoon—tour of city, followed by a tea at the Milwaukee Engineers' Society building
Tuesday evening—informal dinner with Ednah Nichols giving her demonstration on remodeling and trimming hats

Wednesday, October 20
Tour of art institutes and historical societies
Wednesday evening—dinner-dance

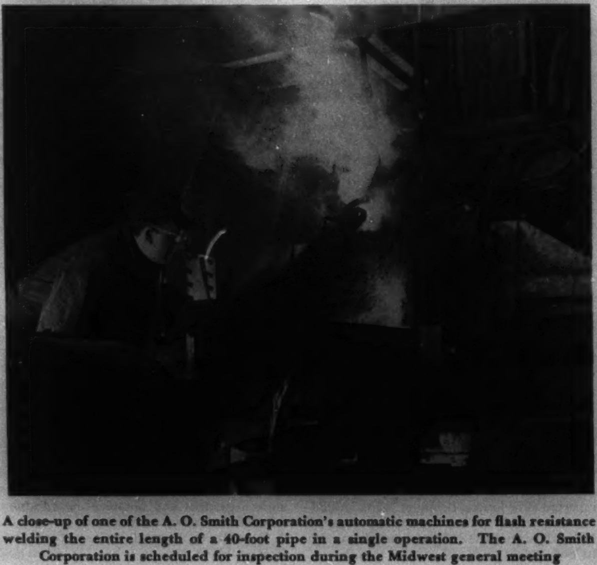
Thursday, October 21
Bridge luncheon at Tripoli Country Club

Friday, October 22
Hostess parlor will remain open
No planned entertainment

Hostess parlors will be open during entire meeting. Local committee women will be present at all times to arrange card games and give information on shopping centers, theaters, and points of interest.

HOTEL RESERVATIONS

The housing committee requests that all members write direct to the hotel of their choice for hotel accommodations. They also suggest that members make their reservations as early as possible (before October 1, 1948) and do not wait to receive the advance



A close-up of one of the A. O. Smith Corporation's automatic machines for flash resistance welding the entire length of a 40-foot pipe in a single operation. The A. O. Smith Corporation is scheduled for inspection during the Midwest general meeting

registration forms and other mailings on the meeting.

The selection of someone to share a twin-bed room is desirable.

Arrangements have been made with the following four hotels to honor reservations from members:

The Schroeder Hotel (headquarters)
The Pfister Hotel
The Plankinton House
The Wisconsin Hotel

Rates on rooms are as follows (all with bath):

Single	$ 3.50–$ 7.70
Double	$ 5.50–$10.00
Twin beds	$ 7.00–$12.00
Suites	$16.00–$25.00

Electric Welding Conference Scheduled for Detroit

Today's problems and tommorrow's progress in arc and resistance welding will receive attention at the AIEE technical conference on electric welding to be held in Detroit, Mich., December 6, 7, and 8, 1948. Both arc and resistance welding sessions are on the schedule, which also includes an automobile plant inspection trip and an informal evening's entertainment. Meeting headquarters will be the Rackham Memorial Building. Purpose of the technical conference is to encourage interchange of ideas and requirements among electric welding users, equipment manufacturers, and utilities. Discussions and forums will be wire-recorded for publication along with technical papers on a conference proceedings book.

Arc welding sessions will devote attention to inert arc welding, radio interference problems, electrical characteristics of welding arcs, new equipment requirements, and so forth. Related sessions on welder power supply and distribution will consider these problems both within the industrial plant and from the utility standpoint. New and more accurate methods of determining the effects of welder loads on power systems will be discussed.

Maintenance, use of instruments, and maintenance training will keynote an evening session expected to attract a large local audience from Detroit industrial plants.

One session will be devoted to the discussion of the relative merits of 3-phase versus single-phase welding and the effect of various wave shapes in the welding results. Recent information indicates that the wave shape has a definite bearing on welding results for certain applications.

Sponsoring the December conference is the AIEE committee on electric welding in co-operation with the Michigan Section, AIEE and the Detroit Section, American Welding Society. Conference chairman is E. H. Vedder, Westinghouse Electric Corporation, Buffalo, N. Y. G. W. Garman, General Electric Company, Schenectady, N. Y., is program committee chairman. Local committee chairman is Myron Zucker, Royal Oak, Mich.

Advance registration forms and hotel information, may be obtained from L. E. Donelson, 1365 Cass Avenue, Detroit 26, Mich.

Lamme Medal Nominations To Be Submitted by December 1

Members of the Institute again are reminded that they have an opportunity to submit nominations for the 1948 Lamme Medal. All nominations must be received not later than December 1, 1948. Details regarding qualifications have been published in *ELECTRICAL ENGINEERING* (*EE, June '48, p* 608).

The 1947 Lamme Medal was awarded to A. M. MacCutcheon retired vice-president of the Reliance Electric and Engineering Company, Cleveland, Ohio, and a past president (1936–37) of the AIEE. Addresses delivered in connection with the presentation of the medal and the medalist's career appeared in last month's *ELECTRICAL ENGINEERING* (*EE, Aug '48, pp 749–53*).

General Committee Appointed for 1949 Summer Meeting

According to a recent announcement, AIEE President Lee has appointed the follow-

Future AIEE Meetings

Middle Eastern District Meeting
Hotel Statler, Washington, D. C.
October 5–7, 1948
(*Final date for submitting papers—closed*)

Midwest General Meeting
Schroeder Hotel, Milwaukee, Wis.
October 18–22, 1948
(*Final date for submitting papers—closed*)

Southern District Meeting
Birmingham, Ala.
November 3–5, 1948
(*Final date for submitting papers—closed*)

AIEE/IRE Conference on Electronic Instrumentation in Medicine and Nucleonics
Engineering Societies Building
New York, N. Y.
November 29–December 1, 1948

AIEE Conference on the Textile Industry
Atlanta, Ga.
Fall, 1948

AIEE Conference on Electric Welding
Engineering Society on Detroit Building
Detroit, Mich.
December 6–8, 1948

AIEE Conference on High-Frequency Measurements
National Bureau of Standards,
Washington, D. C.
January, 1949

Winter General Meeting
Pennsylvania Hotel, New York, N. Y.
January 31–February 4, 1949
(*Final date for submitting papers—November 16*)

AIEE Conference on the Textile Industry
Boston, Mass.
Spring, 1949

AIEE Conference on Electron Tubes
March, 1949

AIEE Conference on the Rubber and Plastics Industry
Akron, Ohio
March, 1949

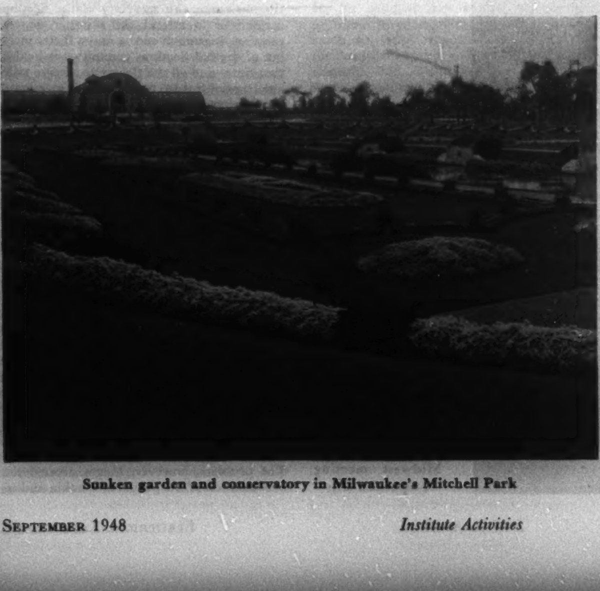
South West District Meeting
Dallas, Tex.
April 19–21, 1949

Summer General Meeting
New Ocean House, Swampscott, Mass.
June 20–24, 1949

Pacific General Meeting
Fairmont Hotel, San Francisco, Calif.
August 23–26, 1949

Midwest General Meeting
Cincinnatti, Ohio
October 17–21, 1949

AIEE Conference on Industrial Power Distribution
Date to be announced



Sunken garden and conservatory in Milwaukee's Mitchell Park

ing general committee to make plans for the 1949 summer general meeting to be held in Swampscott, Mass., June 20–24, 1949: E. W. Davis, *general chairman;* M. A. Princi, *vice-chairman;* Ralph E. Muehlig, *secretary-treasurer;* R. G. Porter; F. P. Taugher; R. G. Slauer.

In addition, the following committee chairmen have been appointed: A. Lee O'Banion, *registration;* R. G. Connors, *hotels;* J. O'R. Coleman, *meetings and papers;* H. B. McIntyre, *publicity;* J. M. Whittenton, *inspection;* F. S. Bacon, Jr., *hospitality;* G. J. Crowdes, *smoker and banquet;* Chester A. Corney, *finance;* Mrs. Fred Haeussler, *ladies' committee;* A. B. Whitehouse, *transportation;* E. W. Boehne, *Student activities;* L. P. Shildneck, *sports.*

AIEE PROCEEDINGS

Order forms for current AIEE *PROCEEDINGS* have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of AIEE *PROCEEDINGS* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *TRANSACTIONS.*

AIEE *PROCEEDINGS* are an interim membership service, issued in accordance with the revised publication policy that became effective January, 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*). They are available to AIEE Student Members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *PROCEEDINGS* will appear in *ELECTRICAL ENGINEERING* in abbreviated form.

Location of Order Forms	Meetings Covered
Apr '48, p 49A	Winter general
Aug '48, p 45A	Great Lakes District North Eastern District Summer general

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Section Operation and Management Topic at Summer Meeting Conference

With an attendance numbering 74 Section delegates and representatives of 7 Districts who are either District officers or officers-elect, a conference on Section operation and management was held on June 23, 1948, during the AIEE summer general meeting in Mexico, Federal District, Mexico. Chairman at the session was J. C. Strasbourger of the Cleveland Section, chairman of the Sections committee.

MODEL SECTION

A highlight of the conference was the discussion of the outline of an AIEE model Section, a copy of which previously had been forwarded to all Sections for consideration. This outline of model Section activities had been perfected under the direction of Fischer Black, Sections committee member from the Washington Section. It was designed to assist new Section officers as a guide and check-sheet for each item of successful Section operation. The concensus of opinion as brought out by the discussion indicated that the outline should be useful for the guidance of Section officers but that the proposed rating scheme was of questionable value. The chairman reiterated, however, that the project is in the development stage and that the Sections may be asked later how far they have found it advantageous to follow the pattern of activities shown in the outline. The outline was approved by the conference for use as a guide for Section management.

COMMITTEE REPORTS

A major portion of the conference was devoted to the presentation and discussion of the reports of committees which have been considering various topics pertinent to Section activities. One of these, the prize paper subcommittee, following the presentation by District 2 Vice-President C. W. Bower of the history of the various revisions of the rules covering prize papers, submitted a draft of proposed new rules. This draft subsequently will be circulated to the Sections and to the Student Branch counsellors for consideration and for comments regarding its suitability for offering to the committee on award of Institute prizes.

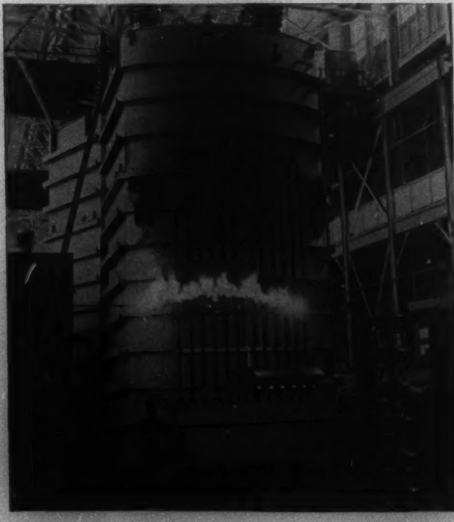
A discussion of a report prepared by D. E. Moat, chairman of the committee on transfers, brought out the fact that all but approximately ten Sections have appointed transfers committees and that there is active interest in the Sections in encouraging transfers as well as in the requirements for such transfers of membership. The general point of view was that the recent constitutional amendment regarding transfers to Fellow grade should be revised to permit proposals to be signed by either Fellows or Members, as formerly, and a motion was carried to present to the board of directors a suggestion to that effect.

Another question which was considered was that of Section finance, which had been raised at the winter general meeting at which time a special committee was appointed to look into the matter and report. However, the report of that committee, the subcommittee on Section finances, recommended that no changes be proposed at the present time in the method of Section financing. In regard to traveling expenses for Sections committee officers, it was decided that the conference recommend to the AIEE board of directors that provision be made in the Institute's budget for mileage payments to the chairman and secretary of the Sections committee to attend the summer general meeting, inasmuch as the only official meeting of the full Sections committee is held at that time, and all the delegates receive mileage to permit them to attend this meeting of the Sections committee.

The subject of technical group activity also was discussed, and a number of Sections reported the organization of such groups.

INTERNATIONAL SECTION

A proposal by J. A. Persson of the Niagara Frontier Section, made in a letter read by Chairman Strasbourger, inspired unanimous agreement regarding the desirability of establishing of a new Section at Niagara Falls. The territory of the new Section was suggested to include Niagara Falls, N. Y. (now included in the Niagara Frontier Section) and Niagara Falls, Ontario, Canada (now included in the Toronto Section). This proposed Section territory now lies partly in District 1 (North Eastern) and partly in District 10 (Canada). It is desired by the Niagara Falls people on both sides of the boundary that the new Section should be a part of neither District 1 nor District 10, but should be international in character. The problem, however, hinges around the classification of the proposed Section and its



A 1,210-kv chopped wave test on a 25,000-kva 132/220-kv high-voltage transformer at the Allis-Chalmers Manufacturing Company, Milwaukee, and subject of a Midwest meeting inspection trip

affiliation with a suitable District. The conference went on record as favoring the establishment of the proposed Section at Niagara Falls recommending as a compromise that the new Section be affiliated with District 3 (New York City) until such time as the vice-presidents of District 1 and District 10, together with AIEE President E. S. Lee, if available, shall meet with the officers of the new Section and determination be made of its final District affiliation.

BYLAWS CHANGES

As a result of proposals made at the conference, recommendations will be made to the board of directors for the following changes in the bylaws of the Institute:

1. That mileage payments be made for representatives of each Subsection to attend District meetings, as well as representatives of each Section within the District.
2. That a Section be permitted to send alternates to District meetings in the event that the regular delegates cannot attend.

WOMEN'S AUXILIARIES

A description of the Philadelphia Section plan, whereby a women's auxiliary composed of the wives of members of the Section has been instituted, provided the final topic of the conference. This auxiliary has no official status but provides an opportunity for certain social activities which are found to be very helpful and the Section regards the auxiliary as highly successful. A number of other members agreed that women's auxiliaries are desirable adjuncts to AIEE Sections. However, the chairman summed up the discussion by stating that no action was required by the conference on the matter, but that if any Section wished to form a women's auxiliary, it certainly should proceed to do so.

This report on the summer meeting conference on Section management and operation was based on notes submitted by W. J. Barrett, acting secretary of the conference.

President Lee Addresses Meeting of Delegates

Under the chairmanship of J. C. Strasbourger, chairman of the Sections committee, a delegates get-together was held on June 22, 1948, during the AIEE summer general meeting in Mexico City. The delegates were welcomed officially by Manuel M. de Lascurain, chairman of the general attention committee, and Mr. Strasbourger expressed the appreciation of the Institute for the hospitality of the Mexico City Section which had acted as host during the summer meeting.

Feature of the get-together was an address by AIEE President Everett S. Lee, who spoke briefly about the importance of the Section in Institute affairs. He brought out the fact that the 29,000 members and 14,000 Student members, with few exceptions, all take part in Section 2 activities, and he emphasized the point that the delegates present at the get-together undoubtedly will take a large part in directing the activities of the Sections for the coming year. The Sections, he said, are the Institute. Mr. Lee referred to the activities of the Student Branch counselors and to the work of the technical committees of the Institute, and he urged that consideration be given by the Sections to covering all the varied interests of the members of the Sections, and encouraged the Sections to help the Student Branches in their respective areas. He also spoke of the efforts which are under way looking toward the establishment of an over-all national engineering organization and indicated that these efforts will be continued although there is considerable inertia to be overcome. During his term as president, Mr. Lee will write a "President's Message" each month for publication in *ELECTRICAL ENGINEERING*, on the general topic of "Our Institute." He closed his address to the delegates with this thought:

> Each of you represents a certain number of members of the Institute. Be sure you are giving every opportunity possible for the participation of every member of the Institute in Sections activities. In this way, we will go forward to even a greater year.

The meeting of delegates was concluded with the presentation of a scroll to Señor Lascurain by Doctor J. C. Leitch, chairman of the Cleveland Section. This scroll, prepared by the Cleveland Section, expressed to the Mexico City Section deep appreciation for the many courtesies and generous hospitality offered to AIEE members by the Mexico City Section during the 64th summer general meeting.

PERSONAL NOTES.......

J. M. Todd (M '32, F '45) New Orleans, La., consulting engineer, has been nominated for next president of the American Society of Mechanical Engineers. Born in St. Mary Parish, La., in 1896, he was graduated from the college of engineering of Tulane University in 1914, receiving a graduate degree in mechanical engineering in 1930. He enlisted during World War I and was sent to England and France as an officer on the Engineer Corps. Following the war he was employed by Penick and Ford, Ltd., as chief engineer of their Morrero, La., plant, and later was with A. M. Lockett and Company, New Orleans. In 1928 he established private practice as consulting mechanical and electrical engineer, specializing in air-conditioning, power plants, and the equipment of large buildings and factories. He has been responsible for many important installations in the New Orleans and Houston (Tex.) areas. As vice-president and member of the board of the Jefferson Lake Sulphur Company, in charge of engineering, Mr. Todd has had mining assignments in Mexico and Central and South America. He is recognized as one of the leaders in the mining and production of crude sulphur. During World War II, he handled mechanical and electrical problems in connection with airfields, shipyards, and other important defense work for the Army, the Navy, and the Maritime Commission. Mr. Todd has been active in national and local affairs of both the American Society of Mechanical Engineers and AIEE. He organized the New Orleans Section of the AIEE and was its first chairman. He was president of the Louisiana Engineering Society in 1930 and served for six years on its board. He was AIEE Section (New Orleans, La.) chairman from 1933 to 1935.

Oscar A. Wilde (A '27, M '34) assistant electrical engineer, Sun Shipbuilding and Drydock Company, Chester, Pa., has been appointed chairman of the AIEE committee on marine transportation for 1948–49. Born in Philadelphia, Pa., Mr. Wilde attended Drexel Institute of Technology, graduating in 1918 with a degree in electrical engineering. From 1918 to 1920 he worked as a marine electrical draftsman for the Pusey and Jones Shipbuilding Corporation, Gloucester, N. J. From 1920 to 1940 he was electrical draftsman and chief electrical draftsman for the Sun Shipbuilding and Drydock Company. Since 1940 he has been assistant electrical engineer in the electrical design department in charge of the electrical design for ships. During World War II he was a member of the committee on the development of American War Standards. He is a member of the American Society of Naval Architects and Marine Engineers, and has been a member of the AIEE committee on marine transportation since 1927, and was chairman of subcommittee on fittings and appliances of the AIEE Marine Transportation Committee for 1947–48.

G. S. Lunge (A '23) central station engineering division, General Electric Company, Schenectady, N. Y., has been made chairman of the AIEE substation committee for 1948–49. Born in London, England, he came to British Columbia in 1913, moving to the United States in 1914. He attended the University of Washington and also the University of California from which he was graduated in 1922 with a bachelor of science degree in electrical engineering. He has been an employee of the General Electric

J. M. Todd

O. A. Wilde

G. S. Lunge

Company, Schenectady, N. Y., from September 1922 to the present. From 1922 to 1923 he was in the testing department, and from 1924 to 1927 he was in the switchgear engineering department. Since then he has been in the central station engineering division. He has served on the automatic stations committee, predecessor of the substations committee, and on the instruments and measurements committee. He also served on the joint subcommittee on power systems applications of carrier current, predecessor of the present carrier current committee. He has been chairman of the joint subcommittee on telemetering (1946–48), is a member of the AIEE sectional committee on power switchgear C37, and has been secretary of this committee since its organization in 1933. He is a member of the sectional committee Z32, electrical symbols, and was previously a member of the electrical definitions committee, C42. He is a coauthor of a number of Institute papers, and is a member of Eta Kappa Nu and an associate member of Sigma Xi.

Walther Richter (M '37, F '42) consulting engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been made chairman of the AIEE committee on basic sciences. A graduate of the Institute of Technology, Karlsruhe, Germany, with a bachelor of science degree in electrical engineering, Mr. Richter joined the Allis-Chalmers Company as a draftsman in 1924. In 1926 he entered the employ of the A. O. Smith Corporation as director of electrical research and engineering, but in 1939 he left to become a consulting engineer. Mr. Richter rejoined the Allis-Chalmers Manufacturing Company in 1943 in this latter position. Since 1935 he has been a teacher at the University of Wisconsin, extension division, instructing in industrial electronics, and is the author of a text on this subject published in 1947. He also has written many articles on electronics and electrical engineering. He is a member of the Wisconsin Society of Professional Engineers, and was co-ordinating chairman of the electrical discussion group in 1940–41, and chairman of the basic sciences group in 1943. He has been a member of the AIEE committee on basic sciences from 1942 to 1946 and in 1945–46 was program chairman of the Milwaukee section of the Institute of Radio Engineers.

Charles Concordia (F '46) engineer of the analytical division of the General Electric Company's central stations engineering divisions, Schenectady, N. Y., has been made chairman of the AIEE committee on computing devices for 1948–49. Mr. Concordia joined the General Electric Company in 1926 as a laboratory assistant working on instrumentation. In 1931 he took the General Electric test course and from 1932 until 1936 he worked on special engineering problems in a number of company divisions. In 1936 he was made application engineer in the central stations engineering division. Mr. Concordia is a member of the American Society of Mechanical Engineers and is the holder of many patents on electric apparatus. He is the author of many AIEE papers and his AIEE committees include basic sciences (1944–48), computing devices (1947–48), chairman (1948–49), Standards (1947–48), and technical program (1947–48).

F. R. Benedict (A '40, M '47) manager of the industry engineering department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been named chairman of the AIEE chemical, electrochemical, and electrothermal committee for 1948–49. Mr. Benedict was graduated from Tri-State College, Angola, Ind., in 1928 with a bachelor of science degree in electrical engineering. In 1928 he became associated with the Westinghouse Electric Corporation, entering their student course. In 1936 he was made engineer in charge of the impulse laboratories, and in 1938 became liaison engineer on the chief engineer's staff. He was made manager of the engineering service department of the New England district in 1941 and in 1943 became manager of the products performance analysis section before becoming manager of the industry engineering department in 1945. He has been a member of his present committee since 1946, and his other AIEE committees include industry power systems (1946–48), industry co-ordination (1947–48), and Standards (1947–48).

Earle Wild (A '27, M '36) chief load dispatcher of the Commonwealth Edison Company, Chicago, Ill., has been made chairman of the AIEE systems engineering committee for 1948–49. Mr. Wild was graduated from the Massachusetts Institute of Technology in 1924 with a bachelor of science degree in electrical engineering. Since graduation he has been with Commonwealth Edison Company, beginning as station operator, in the northwest station (1924–27), and serving as assistant efficiency engineer, load dispatcher, and technical assistant to the chief load dispatcher. In 1942 and 1943 Mr. Wild served on the staff of the Office of War Utilities, War Production Board, as power co-ordinator for New England and other eastern states. In 1944, on his return to the Commonwealth Edison Company, he was appointed assistant chief load dispatcher and in September 1947 became chief load dispatcher.

R. I. Parker (A '14, M '20) formerly manager of apparatus department, central district, General Electric Company, Chicago, Ill., has been elected a commercial vice-president it was announced recently. Mr. Parker was graduated from the University of Kansas (bachelor of science) in 1912, and entered the General Electric test course. In 1913 he was transferred to the lighting engineering department, and in 1919 he joined the sales force in the Chicago office, becoming assistant manager of apparatus sales in 1921. He was appointed district manager of the General Electric central station department in 1924, and assistant district manager of the central district in 1941. Mr. Parker is a member of Tau Beta Pi, and the Chicago Engineers Club.

M. J. Kelly (M '26, F '31) executive vice-president of Bell Telephone Laboratories, Inc., has been named chairman of the newly formed committee on navigation of the Office of the Secretary of Defense. The new committee was formed after a 6-months study by the research and development board of over-all problems related to land, marine, and air navigation. Doctor Kelly served as a member of the board and the ad hoc committee appointed by the board to study the problem. Doctor Kelly has been with his present organization since receiving his doctor of philosophy degree from the University of Chicago in 1918. He is a member of the National Academy of Sciences, the American Physical Society, the Institute of Radio Engineers, and the Acoustical Society of America, and has authored a number of Institute papers. He holds honorary degrees from the University of Missouri and from the University of Kentucky and received the Presidential Citation of Merit in 1948 as a recognition of his help to the war effort. He was on the communication and Standards committees from 1934 to 1937, and from 1934 to 1939 and 1941 to 1943, respectively.

W. O. Batchelder (A '08) formerly commercial vice-president, General Electric Company, Chicago, Ill., has retired after 43 years service with that company. Upon his

Walther Richter

C. Concordia

F. R. Benedict

Earle Wild

R. I. Parker

graduation from Harvard University in 1905, Mr. Batchelder joined the General Electric Company and served for several years with the industrial engineering department. He was later with the industrial commercial department and in 1912 he joined the central district, in charge of motor sales in Minneapolis. He served in Butte, Mont., in Detroit, Mich., and in 1917 went to the Chicago office as manager of the industrial department. In this office he was successively district manager of apparatus sales, district sales manager, and assistant district manager. He was appointed manager of the central district in 1929, and became a commercial vice-president in 1934. Mr. Batchelder is a member of the Western Society of Engineers, the Chicago Electric Club and the Chicago Engineers Club.

B. R. Teare, Jr. (A '29, F '42) Buhl professor of electrical engineering, Carnegie Institute of Technology, has been appointed chairman of the AIEE committee on education for 1948–49. He was graduated from the University of Wisconsin with a bachelor of science degree in 1927, and received his master's degree there in 1928; he received his doctorate from Yale University in 1937. From 1928 to 1933 he was associated with General Electric Company, Schenectady, N. Y., in various positions, and from 1933 to 1939 he was an instructor and later an assistant professor of electrical engineering at Yale University. Since joining the faculty of the Carnegie Institute in 1939 he has been connected with graduate level work. In 1941 he received honorable mention as an author of a paper in theory and research for the AIEE national prize award, and in 1943 he received the prize as coauthor of the prize paper.

J. J. Smith (A '19) assistant engineer, general engineering laboratories, General Electric Company, Schenectady, N. Y., has been made chairman of the AIEE nucleonics committee for 1948–49. A graduate of the University of London (bachelor of science in engineering), The National University of Ireland (master of science), and the Associate Royal College of Science for Ireland (master of arts), Mr. Smith joined the General Electric Company in 1916 in the switchboard test department. From 1917 to 1918 he was in the general test department and in 1918 entered the transformer engineering department in the Pittsfield, Mass., branch of the company. He was formerly a member of the AIEE committee on basic sciences from 1940 to 1941 and from 1944 to 1946.

R. E. Smith (A '31) vice-president and manager, telephone division, Federal Telephone and Radio Corporation, Newark, N. J., has been made chairman of the AIEE communication committee for 1948–49. From 1912 to 1917 Mr. Smith was a draftsman and engineer's assistant of the American Telephone and Telegraph Company, Norwalk, Mass., and from 1917 to 1929 he was telephone engineer in the development and research department of the American Telephone and Telegraph Company in New York, N. Y. From 1929 until joining his present organization he was communications engineer, International Communications Laboratories, New York, N. Y. He was a member of the communication committee from 1941 to 1946.

F. W. Lawton (A '25, M '36) formerly assistant chief engineer with Aluminum Company of Canada, Ltd., Montreal, Quebec, Canada, recently was appointed head of the newly formed power department of Aluminum Laboratories, Ltd. Mr. Lawton was closely associated with the wartime expansion of power and other plant facilities of the aluminum company, especially Shipshaw. He is a former Canadian vice-president of AIEE and has taken a leading part in Canadian engineering activities in the hydroelectric power field. In his new position he will continue his close connection with the investigation, design, and construction of water-power facilities.

F. A. Lane (A '19, M '31) assistant electrical engineer, American Gas and Electric Service Corporation, New York, N. Y., has been named chairman of the AIEE switchgear committee for 1948–49. Mr. Lane was born in Gloucester, Mass., and studied electrical engineering at the Massachusetts Institute of Technology and at Harvard University. In 1919 he joined the General Electric Company Schenectady, N. Y., in the test department, and from 1920 to 1922 he was with the Consumers Power Company, Jackson, Mich., in the electrical engineering department. From 1923 to 1924 he was with the Stone and Webster Engineering Corporation, Boston, Mass., in the drafting division, and in 1925 he joined the American Gas and Electric Service Company in the electrical engineering department.

William Arthur (A '12, M '17) former Philadelphia district office manager for the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been appointed head of a new region in the field organization of that company's general machinery division. The new area, designated as mid-Atlantic, will embrace territory on the middle eastern seaboard. A graduate of the University of Liverpool in England, Mr. Arthur was manager of the heavy traction department of the Brown-Boveri Electric Corporation, Camden, N. J., when that concern was purchased in 1931 by the Allis-Chalmers Company. He was a special representative in the Allis-Chalmers Philadelphia office for eight years before being named district manager.

M. H. Gray (A '45) associate aircraft supervisor in the aircraft armament laboratory, Wright *Patterson* Field, Dayton, Ohio, has received an award for his suggestion to the Air Materiel Command Headquarters for the design and development of an interval and dwell tester for a bomb release interval control, a device which has saved the government $564,000 annually. Before joining the Air Technical Service Command at Wright Field in 1943, he had been owner and active executive with the Gray Electric Company, Springfield, Ohio since 1913.

W. F. Daly (A '20) who has been manager of the power section of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., in the steam turbine department since 1943, has been appointed manager of the Cincinnati district office for that company. An electrical engineering graduate of Pratt Institute, he has been connected with the Allis-Chalmers Company since 1923. He was an officer of the AIEE Chicago Section of the AIEE for many years.

F. S. Black (A '34, M '44) formerly assistant to the president, Potomac Power Company, Washington, D. C., and now editor of *Electrical World*, has been appointed chairman of the AIEE membership committee for 1948–49. Mr. Black is a graduate of the University of North Carolina (bachelor of science in electrical engineering) and of the National Law School (bachelor of laws) and is a member of the District of Columbia bar. He joined his present company in 1934.

Allan Coggeshall (A '05) former secretary and treasurer of Hatzel and Buehler, Inc., New York, N. Y., is organizing his own company which will specialize in the economics of electrical engineering. He is a graduate of Columbia University (1903), with a degree in electrical engineering, and has served on the AIEE subcommittee on interior wiring design.

C. S. Purnell (A '29, M '35) mining sales engineer, industrial department, Westinghouse Electric Corporation, New York, N. Y., has been made chairman of the AIEE headquarters committee for 1948–49. He joined the Westinghouse Company in 1924 as application engineer in railway equipment. He has served on a number of AIEE committees, among them midwinter convention committee (1929–35) and transportation (1929–35, vice-chairman 1932–33, chairman 1934–35).

D. H. Sheats (A '45) who joined the Pieper-Lillard Corporation, St. Louis, Mo., last March, has been named vice-president and sales manager of the company. A graduate of Purdue University in 1931, he entered Commonwealth Edison Company's central institute training course at Chicago, Ill. Four years later he joined the Line Material Company as field engineer, operating the Kansas City, Mo., and Wichita, Kans., trade area. Subsequently he was appointed St. Louis branch manager for the company. He is active in the Electrical Board of Trade, St. Louis, and the Society of American Military Engineers.

M. E. Skinner (M '46) formerly director of sales, has been named vice-president of the Union Electric Company, St. Louis, Mo. He will continue in charge of commercial operations. He was for ten years vice-president in charge of sales for the Buffalo Niagara and Eastern Power Corporation before joining Union Electric. He has served with the Duquesne Light Company, Pittsburgh, Pa., as commercial manager and with the New York (N. Y.) Power and Light Corporation as commercial manager and vice-president. He served on the AIEE membership committee from 1921 to 1924 and on the special committee on Institute prizes from 1925–6.

S. C. Leyland (A '40, M '43) section engineer meter engineering department, Westinghouse Electric Corporation, Newark, N. J., has been reappointed chairman of project 4 (working group on high-frequency characteristics of power equipment), and appointed chairman for project 6 (working group on standard terminology for carrier current) and project 8 (working group on use of microwave equipment for relaying telemetering and supervisory control) of the AIEE carrier current committee for 1948–49, and also has been appointed chairman of subcommittee 4 (project committee on Standards for power relays) of the AIEE relay committee for 1948–49.

O. J. Miller (M '41) who has been superintendent of operations since 1943 for the Duke Power Company, Charlotte, N. C., has been appointed general manager. In 1916 Mr. Miller joined E. W. Clark and Company of Columbus, Ohio, as engineer, after graduating from Ohio State University. In 1920 Mr. Miller went to the Tennessee Electric Power Company as engineer in charge of various operations in construction activities. He was made production superintendent after four years and was production and transmission manager from 1928 to 1939. In 1940 he joined the Commonwealth and Southern Corporation at Jackson, Mich., and became associated with his present company in 1943. He is a member of the American Society of Chemical Engineers.

E. H. Eacker (A '25) has been elected president of the Boston (Mass.) Consolidated Gas Company. A graduate of Massachusetts Institute of Technology, he joined the Charlestown Gas and Electric Company in 1923 as electrical superintendent. From 1930 to 1931 he was the local manager. In 1931 he joined his present company, serving as an assistant to the vice-president in charge of the Boston district. In 1937 he was made assistant to the general manager and assistant to the president. He was made vice-president in 1942. He is also a member of the American Gas Association and the New England Gas Association.

Dudley Sanford (A '25) who has been executive assistant of the Union Electric Company, St. Louis, Mo., has been named vice-president in charge of the electric operations of the company, and of the Union Colliery Company and the St. Louis and Bellville Electric Railway. A graduate of the University of Missouri and Princeton University, he was employed by the Utah Power and Light Company before joining his present organization in 1919 as industrial engineer in the sales department. He was treasurer of the St. Louis County Gas Company, and an assistant treasurer of Union Electric from 1923 to 1944.

E. S. Bundy (A '14, F '33) has been elected vice-president and chief engineer of the Niagara Hudson Power Corporation, Syracuse, N. Y. A graduate of Cornell University, Mr. Bundy's early career was with the Buffalo Niagara Electric Corporation, Buffalo N. Y. He served successively as draftsman, division superintendent, chief electrical engineer for the western division, director, vice-president and chief engineer. He served on AIEE committees for electrical machinery (1931–8) and power transmission and distribution (1932–6).

R. C. Muir (A '08, F '36) former general manager, apparatus department, General Electric Company, Schenectady, N. Y., who recently retired after more than 42 years service with that organization, has returned from retirement. He will be general manager of the nucleonics department of the Hanford Works, Richland, Wash., which General Electric Company is operating for the Atomic Energy Commission. His career with the company, which included serving on the president's staff as vice-president in charge of engineering, was reviewed in *ELECTRICAL ENGINEERING*, February 1948, page 197.

A. D. Bailey (A '39, M '46) who is vice-president and chief operating engineer of the Commonwealth Edison Company, Chicago, Ill., has been appointed chairman of the heating plant and services division of the Illinois Institute of Technology's $15,000,000 development program. Mr. Bailey is a past president of the board of trustees of the Lewis Institute, a vice-chairman of the board of trustees of Illinois Institute Technology and a fellow and past president of the American Society of Mechanical Engineers.

T. E. Roach (A '45) executive vice-president and general manager of the Idaho Power Company, Boise, has been elected chairman of the board and president. Before joining his present company, Mr. Roach was with the Northwestern Electric Company, Portland, Oreg., as vice-president and general manager. Mr. Roach was operating head of the Washington Gas and Electric Company from 1932 until he joined the Pacific Power and Light Company as assistant to the president with offices in Yakima, Wash. In 1942 was transferred to the Portland office of the company to assume broader responsibilities connected with wartime system operations. In his new position, Mr. Roach will retain the position as general manager.

F. W. Tatum (M '45) has been promoted to the rank of associate professor of electrical engineering in the School of Engineering, Southern Methodist University, Dallas, Tex. Professor Tatum has been at Southern Methodist University since February 1947. Prior to that, he had been for 11 years in the design and development engineering department of the American District Telegraph Company, N. Y., where he was Section Head in the Engineering Department.

E. P. Yerkes (A '15, M '31, F '40) engineer of equipment and buildings, Eastern area, Bell Telephone Company of Pennsylvania, Philadelphia, has been appointed chairman of the AIEE finance committee for 1948–49. Mr. Yerkes has been with his company since 1912.

J. R. North (A '21, F '41) chief electrical engineer, Commonwealth and Southern Corporation, Jackson, Mich., has been appointed chairman of the AIEE planning and co-ordination committee for 1948–49 Mr. North has been with his present company and its predecessors since 1924. He has served on many AIEE committees in his Institute career.

L. R. Gaty (A '39, M '43) formerly electrical engineer, Philadelphia (Pa.) Electric Company, has been appointed manager of the engineering department. Since 1926 Mr. Gaty had been with the Counties Gas and Electric Company, Norristown, Pa., which later merged with his present company. He served on the AIEE power transmission and distribution committee from 1941 to 1944.

W. D. Howell (A '38) who has been Berkeley district manager for the Pacific Gas and Electric Company since 1946, has been promoted to sales manager of the East Bay division for the company.

Alvah Small (M '37, F '43) formerly president, Underwriters' Laboratories, Inc., Chicago, Ill., has been elected vice-chairman. Mr. Small joined the laboratories' staff in 1906 and in 1910 was placed in charge of the factory inspection work. He became vice-president in 1916 and in 1935 was elected president.

E. W. Starr (A '28, M '36) acting head of the electrical engineering department of the Cooper Union School of Engineering, New York, N. Y., as announced in *ELECTRICAL ENGINEERING* for July, page 714, will be permanent head of that office, with the grade of full professor.

B. A. Fisher (M '45) professor of electrical engineering at the University of Denver (Colo.), has been appointed associate professor at Illinois Institute of Technology, Chicago. He received his bachelor's degree at the University of Missouri and his master's at Harvard in 1937, and from 1941 to 1946 served as commander at the United States Naval Academy, where he taught electrical engineering.

L. W. Matsch (M '41) formerly supervisor in electrical engineering research at the Armour Research Foundation of the Illinois Institute of Technology, has been appointed professor of electrical engineering. He obtained his bachelor's degree at Lewis Institute, predecessor of his present school, and taught part-time at Lewis from 1926 to 1940. From 1927 to 1945 he was also an engineer with the Commonwealth Edison Company.

A. E. Knowlton (M '17, F '30) senior associate editor, *Electrical World*, has been appointed chairman of the AIEE committee on the Edison Medal for 1948–49. Prior to his joining *Electrical World* in 1930, Mr. Knowlton was associate professor of electrical engineering at Yale University. His Institute activities have included many technical committees and papers.

E. D. Doyle (A '09, M '18, F '27) patent engineer, Leeds and Northrup Company, Philadelphia, Pa., has been appointed chairman of the AIEE board of examiners for 1948–49. From 1911 to 1926 Mr. Doyle was with the Electrical Testing Laboratories, Inc., New York. He has been with his present firm since 1926.

Karl Geiges (A '31, M '41) of the Underwriters' Laboratories, Inc., New York, N. Y., has joined the steering committee of a new technical organization, the Standards Engineering Society, whose purpose is to remove barriers that tend to isolate various fields of engineering. He served on the AIEE committee on electronics from 1947 to 1948.

S. J. Beaton (A'45) recently has been appointed to the staff of the industrial heating section of Canadian General Electric Company, Ltd., Toronto, Ontario, Canada. He was graduated from the University of British Columbia in 1944 with a bachelor of arts degree and received his company's "test" training. He is a registered professional engineer.

C. H. Zurheide (A '45) has been appointed project engineer in the substation department of the Union Electric Company, St. Louis, Mo. He was affiliated with the Laclade Power and Light Company when it was acquired by the Union Electric Company in 1945.

F. P. Robinson, Jr. (A '38) has resigned from the staff of Union Electric Company, St. Louis, Mo., to join the General Electric Atomic Research Project, Hanford, Wash. He was with his former company for more than eight years.

L. H. Marotte (A '45) superintending engineer, stations section, Quebec Hydro-Electric Commission, Montreal, Quebec, Canada, has retired. A graduate of McGill University in the class of 1904, he had been with the Commission since 1924. He previously was a member of AIEE from 1921 to 1924.

B. M. Carothers (A '42) who has been project engineer, engineering and construction department, Union Electric Company, St Louis, Mo., has been appointed electrical engineer.

J. F. Craib (A '37) has joined the engineering staff of Airborne Instrument Laboratories, Inc., Mineola, N. Y. He will be engaged in research and development of special-type microwave receivers.

F. C. Todd (A '42) who has been Memphis, Tenn., district manager for the Line Material Company, has been made manager of their protective equipment sales department.

J. C. Strasbourger (A '31, M '40) supervising engineer, electrical department, Cleveland (Ohio) Electric Illuminating Company, has been reappointed chairman of the AIEE Sections committee for 1948–49.

N. S. Hibshman (A '27, M '32, F '41) dean, school of science and technology, Pratt Institute, Brooklyn, N. Y., has been appointed chairman of the AIEE Lamme Medal committee for 1948–49.

Walter C. Smith (A '07, M '26, F '40) retired associate of the General Electric Company, now living in San Francisco, Calif., has been reappointed chairman of the AIEE constitution and bylaws committee for 1948–49.

H. M. Turner (M '20, F '44) associate professor of electrical engineering, Yale University, New Haven, Conn., has been reappointed chairman of the AIEE technical program committee for 1948–49, and of the committee for the award of Institute prizes for 1948–49.

Harry Barker (A' 05, M '13) consulting engineer, Barker and Wheeler, Engineers, New York, N. Y., has been reappointed chairman of the AIEE committee on code of principles of professional conduct for 1948–49.

Robin Beach (A '15, M '21, F '35) consulting engineer, Brooklyn, N. Y., has been reappointed chairman of the AIEE safety committee for 1948–49.

B. M. Jones (A '20, M '24, F '42) planning engineer, planning and development department, Duquesne Light and Power Company, Pittsburgh, Pa., has been reappointed chairman of the AIEE publications committee for 1948–49.

Reginald L. Jones (A '11, M '17, F '31, member-for-life) vice-president, Bell Telephone Laboratories, Inc., New York, N. Y., has been reappointed chairman of the AIEE Standards committee for 1948–49.

C. G. Suits (M '41, F '47) vice-president and director of research laboratory, General Electric Company, Schenectady, N. Y., has been reappointed chairman of the AIEE research committee for 1948–49.

T. G. LeClair (A '24, M '29, F '40) supervising development engineer, Commonwealth Edison Company, Chicago, Ill., has been reappointed chairman of the AIEE professional co-ordinating committee for 1948–49.

OBITUARY • • • • •

William Schrofield Gorsuch (A '07, M '17) retired engineer of economics of the Board of Transportation of the New York City Transit System, died June 13, 1948. Mr. Gorsuch was born in Baltimore, Md., on July 18, 1871, attended Johns Hopkins University, and was graduated in 1898 with a degree in electrical engineering. After graduation Mr. Gorsuch was associated with the late Doctor Louis Duncan, consulting engineer, and later became engineer in charge of the design and construction of the Baltimore Telephone Construction Company. In 1903, he entered the service of Bartlett Hayward and Company, engineers, as assistant engineer in charge of designing and constructing electrically operated equipment for gas plants. In 1905 he became associated with the New York Central Railroad Company as design engineer and was associated in the electrification of Grand Central Terminal and of the Central line. In 1908 he joined the Metropolitan Street Railway Company as assistant electrical engineer in charge of general engineering department. When the Metropolitan Railway Company was taken over the Interborough Rapid Transit Company in 1912, Mr. Gorsuch was made head of a newly created department as engineer of economics. He was engaged in the development and expansion of the power facilities for the existing and projected subways, elevated lines, and surface railways. He was also engineer in charge of evaluation of the entire Interborough Company's property in connection with the seven cent fare case and testified as the company's expert in receivership cases. He was author, and also coauthor with the late H. G. Stott, of several technical papers, presented before AIEE. He served on many AIEE committees throughout his career, among them power generation (1926–36, chairman 1926–28), technical progress (1926–28, 1930–35), publication (1928–36, chairman 1928–31), coordination of Institute activities (1928–34), constitution and bylaws (1931–36, chairman 1931–34), and headquarters committee (1933–36, chairman 1933–36).

William Hemmenway Pratt (A '02, M '04, F '13) who retired in 1940 from his position as the executive consulting engineer at the West Lynn, Mass., works of General Electric Company, died May 29, 1948. He was born at Waltham, Mass., on December 29, 1872, and attended the Massachusetts Institute of Technology, graduating in 1894 with a degree in electrical engineering. In 1895 he entered the testing department of the General Electric Company at Lynn, Mass., and was appointed foreman in charge of the standardizing laboratory. In 1897 he was transferred to the engineering department as assistant in meter and instrument design. He became chief consulting engineer at the West Lynn works and continued in this position until his retirement in 1940. He was noted as an authority in meter design and manufacture, being credited with the design of the first conduction meter manufactured by the company. He had assigned to the company more than 100 patents on meter types. From 1941 to 1945 he was affiliated with the Research Cost Corporation. In 1932 Mr. Pratt represented the United States contribution on meters at the Electrical Congress in Paris. He was recipient of the New England Award by the New England Engineering Societies in 1941. He was a member of the American Society of Mechanical Engineers, and served as Syracuse Section secretary for AIEE from 1942 to 1943 and was chairman of that Section 1943–44. He served also on the joint power factor committee from 1920 to 1921.

Frederick Robert George (A '13, M '25, Member for Life) former engineer of electric operations of the Pacific Gas and Electric Company, San Francisco, Calif., died June 1, 1948. Born September 13, 1880, at Brookings, S. Dak., he attended the University of Southern California and Stanford University. He began his electric career as an oiler and operator in the steam-driven generating plant of the Mutual Electric Light Company, one of the many predecessors of the Pacific Gas and Electric Company, San Francisco. In 1902 he moved to the Bay County's Power Company, another predecessor, and rose to be foreman of a substation. With the incorporation of Pacific Gas and Electric Company in 1905, Mr. George was selected to be an engineer in the new organization with Oakland as the center of his activities. In addition to four years with predecessors he had a 41-year share in the growth of Pacific Gas and Electric Company and developed or initiated many of the devices and methods that speeded its growth. In 1918 he was transferred to headquarters and in 1921 he was promoted to the position of engineer of electric operation. He retired from the company in 1946. He served on the AIEE membership committee from 1926 to 1928.

Harry Nelson Latey (A '04, F '13) retired chief electrical engineer of the board of transportation, New York, N. Y., died July 11, 1948. Mr. Latey was born in Omaha, Neb., October 14, 1870. He attended the Massachusetts Institute of Technology and was graduated in 1893 with the degree of bachelor of science in electrical engineering. Following graduation, Mr. Latey was associated with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. In 1898 he became the assistant engineer of the Manhattan Elevated Railway Company in New York and was in charge of the electrification of the old steam-powered lines. When the Interborough Rapid Transit Company started to make its plans for the first subway in 1904, Mr. Latey was the electrical engineer of both systems. From 1906 to 1912 he was in the firm of Latey and Slater, railroad engineers and contractors, as senior partner. In 1920 he went with the state transit commission as electrical engineer in charge of the equipment division. When the board of transportation absorbed the transit commission in 1924, Mr. Latey became the chief engineer of the division of equipment and operation. He retired in 1944, having continued in his post past retirement age at the special request of the board of transportation which declared his services essential. He was a member of the American Society of Civil Engineers, the Engineers Club of New York City, and served on the AIEE board of examiners from 1918 to 1921 and on the transportation committee from 1931 to 1933 and from 1936 to 1938.

Samuel Poole MacFadden (A '19, M '30) former executive vice-president of Puget Sound Power and Light Company, Seattle, Wash., died on May 23, 1948. Born June 17, 1894 at Laredo, Tex., Mr. MacFadden was graduated from Agricultural and Mechanical College of Texas in 1916 with the degree of bachelor of science in electrical engineering. From 1916 to 1917 he was a graduate apprentice with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. From 1917 to 1919 he served in the coast artillery and in the American Expeditionary Force, rising to the rank of first lieutenant. From 1919 to 1920 he was associated with the Eastern Texas Electric Company, Beaumont, and from 1920 to 1923 he was with the Southwestern district of Stone and Webster, Inc., Houston, Tex., as assistant to the district manager. In 1923 he went with the Eastern Texas Electric Company again, as superintendent in Port Arthur, Tex., where he remained until 1925. From 1925 to 1929 he was manager of a group of electric light and power companies which were consolidated into the Western Public Service Company and the Missouri Service Company, Scottsbluff, Neb. In 1930 he went with Puget Sound Power and Light Company as vice-president and director, becoming executive vice-president in 1942. He resigned in 1946 due to ill health, but continued as a consultant. He was a past president of the Northwest Electric Light and Power Association.

Alexander Hardie Forman (A '16, M '27, F '43) head of the electrical engineering department of the University of W. Virginia, Morgantown, West Va., died June 30, 1948. Doctor Forman was born at Grafton, West Va., on June 12, 1883, and received the degree of bachelor of science in mechanical engineering from West Virginia University in 1906, the electrical engineering degree in 1908. He received his master's degree in mechanical engineering in 1909, and his doctorate degree, in 1912, both from Cornell University. He was a member of the research division, engineering department of the Westinghouse Electric and Manufacturing Corporation from 1906 to 1907, and was assistant in physics, Cornell University, from 1909 to 1910, and instructor from 1910 to 1913. In 1913 he went to West Virginia University as assistant professor of experimental and electrical engineering, and from 1916 until his death was professor and head of the electrical engineering department. He was a member of the American Physical Society and Eta Kappa Nu and served as an AIEE Student Branch counsellor from 1930 to 1947.

Leland Russell Mapes (M '29, F '37) assistant vice-president, Illinois Bell Telephone Company, Chicago, died May 1, 1948. Born on March 26, 1892, in Middletown, N. Y., he was graduated from Columbia University in 1913 with a degree in electrical engineering. From 1913 to 1925 he was an engineer with the American Telephone and Telegraph Company, and was active in the introduction of dial equipment in the Bell system. From 1925 to 1928 he was equipment and building engineer for the Illinois Bell Telephone Company. From 1928 to 1936 he was chief engineer of the Chicago area of that company, and was responsible for design of all telephone plants in the city of Chicago. In February 1938 he was appointed general manager, state area, for the company with supervision of territory outside of Chicago. In 1944 he was appointed vice-president. Mr. Mapes served on the AIEE committees on communication (1938–46), planning and co-ordination (1941–42), technical program (1941–42), Washington award (1942–46), transfers (1934–36), and was a member of the board of directors from 1938 to 1942.

James C. Bowman, Sr. (A '40, M '44) engineer, electric distribution department, Public Service Electric and Gas Company, Newark, N. J., died June 30, 1948. Born on August 15, 1892 in Ramey, Pa., Mr. Bowman received the degree of bachelor of science in electrical engineering from the Newark (N. J.) College of Engineering in 1930. In 1922 he became associated with the Public Service Electric and Gas Company as a test assistant, and since 1923 he had been engaged on system relaying and operating problems. He served on the AIEE relay committee for 1947–48.

Carey White Baker (M '34) chief engineer, English Electric Company of Canada, Ltd., St. Catherines, Ontario, Canada, died July 5, 1948. Mr. Baker was born in Kingston, Ontario, on August 23, 1880. He attended Queens College and was graduated in 1905 with the degree of bachelor of science in electrical engineering. He began his engineering apprenticeship with the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1905, and went with the Canadian Westinghouse Company, Hamilton, Ontario, in 1907. He served as a meter and transformer engineer until 1921, when he went with the engineering department of the Packard Electric Company, St. Catherines, on transformer design. In 1934 he became chief engineer for the English Electric Company and shortly before his death he had been appointed engineering consultant to the vice-president of the company. He was a member of the Canadian Electrical Association, the Canadian Electrical Manufacturers Association, and served as chairman of the Niagara Subsection for 1947–48. He was also an Associate member of AIEE from 1918 to 1930 and served on the committee for instruments and measurements from 1919 to 1922.

Joseph C. Wilson, Jr. (A '44) manager of the Athens, Tenn., Board of Public Utilities, died July 14, 1948. Born on February 13, 1904, in Nashville (Tenn.), Mr. Wilson attended the University of Tennessee and was graduated in 1925 with a bachelor of science degree in electrical engineering. Upon graduation, he entered the student training course of the Westinghouse Electric Corporation at East Pittsburgh, Pa. In 1926 he went with the Eastern division of the Tennesee Electric Power Company as industrial engineer, remaining with this company until joining the Board of Public Utilities as general manager in 1939.

MEMBERSHIP...

Recommended for Transfer

The board of examiners at its meeting of July 15, 1948, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Baker, B. P., dev. engr., switchgear div., Westinghouse Elec. Corp., East Pittsburgh, Pa.

Benkesser, G. E., design & construction engr., Dept. Water & Pr., City of Los Angeles, Calif.
Blakeslee, T. M., transmission & communication engr., Los Angeles Dept. of Water & Pr., Los Angeles, Calif.
Bretch, E., elec. engr., Century Elec. Co., St. Louis, Mo.
Goetzenberger, R. L., vice pres., Minneapolis-Honeywell Regulator Co., Washington, D. C.
Horelick, S., pres. & director, Pennsylvania Transformer Co., Pittsburgh, Pa.
Johnson, E. F., chief engr., Florida Pr. & Lt. Co., Miami, Fla.
Kroneberg, A. A., senior elec. engr., Southern California Edison Co., Los Angeles, Calif.
Minor, E. E., Jr., design specialist, Glenn L. Martin Co., Baltimore, Md.
Rockwell, E. W., senior engr., Metropolitan Water District of Southern California, Los Angeles, Calif.
Sealey, W. C., engineer-in-charge transformer design, Allis-Chalmers Mfgr. Co., Milwaukee, Wis.
Wilhelm, G. R., general plant engr., The Chesapeake & Potomac Tel. Co., Washington, D. C.
Wyatt, K. S., engineer of cables, Phelps Dodge Copper Products Corp., New York, N. Y.

13 to grade of Fellow

To Grade of Member

Ankeney, H. E., elec. engr., Verson Allsteel Press Co., Chicago, Ill.
Baker, M. A., section engr., General Elec. Co., Ft. Wayne, Ind.
Barrett, E. J., elec. engr., General Elec. Co., Richland, Wash.
Bastedo, G. R., electronics engr., National Bureau of Standards, Washington, D. C.
Bell, R. B., engr.; director of engg. lab., King-Sealey Corp., Ann Arbor, Mich.
Bostwick, M. A., application engr., relay sec., Westinghouse Elec. Corp., Newark, N. J.
Broom, C. M., asst. engr., Florida Pr. & Lt. Co., Miami, Fla.
Buchanan, L. W., electrical motor design engr., Westinghouse Elec. Corp., Lima, Ohio
Buus, B. R., engr., lamp dept., General Elec. Co., Cleveland, Ohio
Carral, C. S., mgr., industrial div., General Elec., S. A., Mexico City, Mexico
Clark, F. M., works engr.; technical consultant on insulation, General Elec. Co., Pittsfield, Mass.
Cornbrooks, C. W., elec. engr., Navy dept., Bureau of Ships, Washington, D. C.
Crist, J. A., engr., staff functions, New York Tel. Co., New York, N. Y.
Croxford, F. W., elec. engr., General Elec. Co., Schenectady, N. Y.
Davis, R. H., supervisor of engg. training, Westinghouse Elec. Corp., East Pittsburgh, Pa.
D'heedene, A. R., member of technical staff, Bell Tel. Labs., Inc., New York, N. Y.
Dillow, N. E., application engr., General Electric Co., Schenectady, N. Y.
Doll, H. G., chairman of board; director of research, Schlumberger Well Surveying Corp., Houston, Tex.
Dutton, J. C., power transformer design engr., General Elec. Co., Pittsfield, Mass.
Field, K. S., elec. engr., Ebasco Services, Inc., New York, N. Y.
Freeman, W. C., elec. engr., Ebasco Services, Inc., New York, N. Y.
Funderburg, C. H., supervisor, elec. maint. div., Carbide & Carbon Chem. Corp., Oak Ridge, Tenn.
Giger, W., engr., transportation industries, Allis-Chalmers Mfgr. Co., Milwaukee, Wis.
Hanfmann, A. M., elec. engr., Western Elec. Co., Allentown, Pa.
Hansell, E. B., elec. engr., Gilbert & Barker Mfgr. Co., West Springfield, Mass.
Harris, H. W., consulting elec. engr., Amarillo, Tex.
Harvie, R. A., engr., Canadian Westinghouse Co. Ltd., Hamilton, Ontario, Canada
Hayford, B. I., section engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Hendriks, H. J., quality control staff engr., Collins Radio Co., Cedar Rapids, Iowa
Jewell, L. R., Jr., district engr., Southwestern Bell Tel. Co., Wichita, Kans.
Joseph, W., system planning engr., American Gas & Elec. Service Corp., New York, N. Y.
Keirn, G. F., elec. engr., The Goodyear Tire & Rubber Co., Akron, Ohio
Knightley, W. J., div. plant supt., Southwestern Bell Tel. Co., Wichita, Kans.
Koehne, K. H., head of special devices, USN Office of Naval Research, San Francisco Branch, Calif.
Lang, W. T., mgr., engg. service dept., Control Instruments Co., Inc., Brooklyn, N. Y.
Lebacquz, J. V., asst. prof. of elec. engg., Johns Hopkins Univ., Baltimore, Md.
Maginniss, F. J., application engr., General Elec. Co., Schenectady, N. Y.
Maiese, D. R., elec. engr., power trans. design sec., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Maul, J. A, American Machine & Foundry Co., Brooklyn, N. Y.
McCauley, C., Jr., elec. engr., radio shops, Western Elec. Co., Winston-Salem, N. C.
McNutt, W. K., section engr., General Elec. Co., Schenectady, N. Y.
Meeds, L. T., equipment & bldgs., engr., Chesapeake & Potomac Tel. Co., Washington, D. C.
Miller, C. F., asst. prof., elec. engg., Johns Hopkins Univ., Baltimore, Md.
Peterson, J. P., elec. application engr., Westinghouse Elec. Corp., Binghamton, N. Y.
Peterson, P. O., pres., P & F Construction Co., Inc., Carlisle, Ark.
Pullen, K. A., Jr., elec. engr., P-4, Ballistics Research Labs., Aberdeen Proving Ground, Md.
Reese, D. R., development test engr., General Elec. Co., Schenectady, N. Y.
Ruehlin, W. H., supt. of electrical div., The Electric Auto-Lite Co., Toledo, Ohio
Russell, C., div. engr., Pacific Pr. & Lt. Co., Astoria, Oreg.
Rylance, J. H., senior prof., mechanical (elect.) div., War Assets Corp., Montreal, Que., Can.
Sampson, G. C., telegraph supt., Gulf Refining Co., Houston, Tex.
Schwalbert, W. H., investigation engr., The Toledo Edison Co., Toledo, Ohio
Steidinger, D. K., field engr., Allis-Chalmers Mfgr., Co., Washington, D. C.
Stinson, L. J., power plant design engr., Los Angeles Dept. of Water & Pr., Los Angeles, Calif.
Walters, W. W., toll transmission engr., Illinois Bell Tel Co., Chicago, Ill.
Warchol, M. F., elec. engr., Jackson & Moreland, Engrs., Boston, Mass.
Whitehead, D. L., engr., analog computing lab., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Young, E. L., design section engr., Delco Products Div., General Motors Corp., Dayton, Ohio

58 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before September 21, 1948, or November 21, 1948, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

United States, Canada, and Mexico

Barr, R. O., Barr Hotel, Lima, Ohio
Bednall, C. L., American Cyanamid Co., New York, N. Y.
Bose, P. M., Govt. of India, New Delhi, India
Bray, T. W., Jr., City of Nashville, Nashville, Tenn.
Casciato, R., E. W. Twitchell, Inc., Philadelphia, Pa.
Gettliffe, R., New Consolidated Gold Fields Ltd., Johannesburg, South Africa
Gider, J. E., The Commonwealth & Southern Corp., Birmingham, Ala.
Hamel, J. S., C. E., 241 W. 72nd Street, New York 23, N. Y.
Herring, T. F. (re-election), National Technical Labs., So. Pasadena, Calif.
Hull, D. R., International Tel. & Tel. Corp., New York, N. Y.
Hunter, P. D., San Francisco Naval Shipyard, San Francisco, Calif.
Ibach, J. R., Sr., Aluminum Co. of America, Massena, N. Y.
Iredell, L. N., 914½ Franklin St., Tampa, Fla.
Mitrovitch, M. S., Morgan Elec. Co., Fairbanks, Alaska
Moseman, P. W., Consumers Public Power Dist., O'Neill, Nebr.
Rhinehart, R. J., Arkansas Power & Light Co., Pine Bluff, Ark.
Biggs, H. E., Butler Mfg. Co., Kansas City, Mo.
Saverino, E. V., American Cyanamid Company, New York, N. Y.
Shirely, J. Y., Robert & Co., Inc., c/o Postmaster, San Francisco, Calif.
Wylie, L., Chicago, Milwaukee, St. Paul & Pacific R.R. Co., Seattle, Wash.
Youngson, A. C., Rice & Youngson, New York, N. Y.

21 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. NORTH EASTERN

Corey, C. P., New England Power Co., Millbury, Mass.
Drake, R. K., General Elec. Co., Schenectady, N. Y.
Gummo, R. L. (re-election) Westinghouse Elec. Corp., Buffalo, N. Y.
Leahey, M. T., Sordoni Const. Co., Binghamton, N. Y.
Sullivan, F. W., Rochester Gas & Elec. Corp., Rochester, N. Y.
Watson, E. C., Westinghouse Elec. Corp., Buffalo, N. Y.

2. MIDDLE EASTERN

Clements, C. W., Curtiss-Wright Corp., Columbus, Ohio
Duchesneau, B. E., Curtiss-Wright Corp., Columbus, Ohio
Ferry, J. F., Potomac Elec. Power Co., Washington, D. C.
Fox, S., Sordoni Const. Co., Forty-Fort, Pa.
Frantz, R. L., Hobart Brothers Company, Troy, Ohio
Greer, M. M., Edwin L. Wiegand Co., Pittsburgh, Pa.
Miller, W. H. (re-election) The Hobart Brothers Co., Troy, Ohio
Pierlott, R. G., Jr., Pennsylvania Military College, Chester, Pa.
Reed, E. S., Westinghouse Elec. Corp., Lima, Ohio
Richards, H. H. C., Jr., Westinghouse Elec. Corp., Lima, Ohio
Sanders, P. F., E. I. DuPont de Nemours & Co., Philadelphia, Pa.
Stancati, W. N., The Foxboro Co., Pittsburgh, Pa.
Williams, H. J., Pennsylvania Elec. Co., Johnstown, Pa.
Woods, T. J., Westinghouse Electric Corp., East Pittsburgh, Pa.

3. NEW YORK CITY

Gaylord, W. K., Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
Goldstein, R., Sperry Gyroscope Co., Great Neck, N. Y.
Hardman, J. E., Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
Knerl, R. R., Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
Leader, A. H., Anaconda Wire & Cable, Hastings-on-Hudson, N. Y.
Malmlow, E. G., Elge Associates, New York, N. Y.
Michelson, H. J., 28 E. Monroe St., Paulsboro, N. J.
Putnam, G. P., Westinghouse Elec. Corp., Newark, N. J.
Seaborg, J. W., Westinghouse Elec. Int'l Co., New York, N. Y.
Waters, B. W., Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
Whitener, R. V. (re-election), James Allen Tuck, New York, N. Y.

4. SOUTHERN

Buchanan, L. R., Appalachian Elec. Power Co., Roanoke, Va.
Chapman, C. S., Tenn. Coal, Iron & R.R. Co., Fairfield, Ala.
Clot, O. A., Peninsular Armature Works, Miami, Fla.
Cremer, G. D., Fairchild Engine & Airplane Corp., Oak Ridge, Tenn.
Hanson, H. B., Jr., I. K. Clisby & Associates, Inc., Birmingham, Ala.
Harvie, W. J., Solvay Process Div., Hopewell, Va.
McWhorter, W. P., McDonald Elec. Co. Inc., Miami, Fla.
Paulk, F. D., Jr., TVA, West Point, Miss.
Pickens, C. R., U. S. Rubber Co., Atlanta, Ga.
Winningham, O., National Container Corp., Jacksonville, Fla.

5. GREAT LAKES

Carlson, E. C., Electroline Co., Chicago, Ill.
Carlson, R. E., General Elec. Co., Detroit, Mich.
Evans, W. H., Iowa State College, Ames, Iowa
Gettelman, A. F., General Elec. Co., Minneapolis, Minn.
Griffith, G. R., C. F. Braun & Co., East Chicago, Ind.
Hogan, R. W., Giffels & Vallet Inc., Detroit, Mich.
Koht, F., Precision Scientific Co., Chicago, Ill.
Minieka, E. T., Commonwealth Edison Co., Chicago, Ill.
Salis, N. H., Lafayette Electric Cooperative, Darlington, Wis.
Scherba, M. B., Wayne University, Detroit, Mich.
Tierney, T. E., Commonwealth Edison Co., Chicago, Ill.

7. SOUTH WEST

Dorsett, H. L., Electrical Contractor, Norman, Okla.
Gruesen, K. R., Texas Elec. Service Co., Ft. Worth, Tex.
Jennings, J. E. (re-election), Southwestern Bell Tel. Co., Houston, Tex.
Meyer, M. M. M., Bureau of Reclamation, Amarillo, Tex.
Osborne, M. J., Crossett Paper Mills, Crossett, Ark.
Rubio S., J. L., General Elec. Service Shop, Mexico, Federal District, Mexico

8. PACIFIC

Allan, J. N., Pacific Gas & Elec. Co., San Francisco Calif.
Bergh, E. M., General Elec. Co., San Francisco, Calif.
Cowles, G. D., C. F. Braun & Co., Alhambra, Calif.
Himes, S. T., Spott Electric Co., Oakland, Calif.
Lolmaugh, O. B., Douglas Aircraft Co. Inc., Santa Monica, Calif.
Ohlson, R. L., State of California, San Francisco, Calif.
Spraker, E. G. (re-election) Mathews Conveyer Co., San Carlos, Calif.

9. NORTH WEST

Allehoff, F. A., Bonneville Power Admin, Portland, Oreg.
Lowe, W. E., Bureau of Reclamation, Great Falls, Mont.

Elsewhere

Bowman, H., Braden Copper Co., Sewell, Rancagua, Chile, South America
Collot, M., Societe E.F.L.I., Paris, France
Desai, D. D., 34 Podar Chambers, Parsi Bazar Street, Fort, Bombay, India
Kulatilake, S. A., British Thomson-Houston Co. Ltd., Rugby, England
Madiwale, R. K., Tata Sons Ltd., Bombay, India
Southon, V., Eastern Electrical Board, Bedfordshire, England
Svoboda, J., Literary Dept. of Ceskomoravska-Kolben-Danek, n. p. Praha X, Krizikova 38, Czechoslovakia
Sykes, H., Austral Malay Tin Ltd., Taiping, Malaya

Total to grade of Associate

United States, Canada, and Mexico, 67
Elsewhere, 8

OF CURRENT INTEREST

Edison Foundation Asks Funds for Maintenance of Program

On February 11, 1948, the 101st anniversary of the birth of Thomas Alva Edison, the Edison laboratories at West Orange, N. J., formally were opened to the public by the Thomas Alva Edison Foundation, an organization which was established early in 1947 by leaders in science, education, and industry to carry on in the spirit of progress exemplified by Edison. Under the direction of Vice-Admiral Harold D. Bowen, United States Navy (retired), wartime chief of the Office of Naval Research, the foundation's program includes, in addition to the preservation of Edison's laboratory, the establishment there of the Edison Center for Invention, Discovery, and Research, and the restoration of the nation-wide scholastic competition which was discontinued after Edison's death in 1931.

As part of its program, the foundation also will conduct an investigation of industrial research methods which should prove to be of great value to industry and to the nation as a whole. At the present time research workers are engaged in making an analytical study of the approximately 2,500 notebooks which Edison kept while working on his inventions to determine what techniques of research he utilized to make his own efforts so productive. Results of the studies will be made available to scientists, educators, and research centers, though a series of monographs, the first of which, to be issued early in 1949, will deal with his work on the incandescent lamp.

The restoration of the Edison scholastic competition will involve the award of a 4-year scholarship and will carry forward the purpose of the original Thomas A. Edison scholarship which was to "stimulate the interest of the youth of America in mental development, with particular emphasis on scientific matters and, more generally, in the high ideals that make for the highest type of American manhood." However, consideration of its revival has been deferred to a later date when funds are available.

For the maintenance of these projects, it is estimated that $2,590,000 must be obtained to carry out the foundation's program over a 10-year period. Approximately one million dollars already has been obtained toward the goal and the foundation is confident that the necessary funds will be forthcoming to perpetuate its work. Any contribution, large or small, will be a contribution to the success of the Edison Foundation which, through its service to science, education, and industry will keep alive the spirit of Thomas Edison. A progress report of the foundation's activities will be mailed to donors at appropriate intervals (contributions to the foundation are deductible for Federal income tax purposes.)

The Edison Foundation's program has been approved by the AIEE board of directors and five AIEE representatives have been appointed. They are

T. F. Barton (F '30) General Electric Company, New York, N. Y.; M. D. Hooven (F '44) Public Service Electric and Gas Company, Newark, N. J.; A. E. Knowlton (F '30) *Electrical World*, New York, N. Y.; R. K. Honaman (F '36) Bell Telephone Laboratories, Inc., New York, N. Y.; R. T. Henry (F '33) Buffalo Niagara Electric Corporation, Buffalo, N. Y.

Among the trustees of the Thomas Alva Edison Foundation are the following AIEE members:

C. F. Kettering (F '14) General Motors Corporation, Dayton, Ohio, *president;* K. T. Compton (F '31) Massachusetts Institute of Technology, Cambridge, Mass., *vice-president;* Gano Dunn (F '12, HM '45) J. G. White Engineering Corporation, New York, N. Y., *vice-president;* F. M. Tait (F '12) Dayton Power and Light Company, Dayton, Ohio, *vice-president;* F. B. Jewett (F '12, HM '45) American Telephone and Telegraph Company (retired), Short Hills, N. J.; H. T. Liversidge (F '43) Philadelphia Electric Company, Philadelphia, Pa.; R. A. Millikan (M '22, HM '33) California Institute of Technology (retired), Pasadena, Calif.; David Sarnoff (M '23) Radio Corporation of America, New York, N. Y.

Television Survey First Task of Newly-Formed JTAC

Creation of a Joint Technical Advisory Committee for the purpose of advising governmental agencies, such as the Federal Communciations Commission and other professional and industrial groups on technical aspects of radio, television, and electronic problems, has been announced by the Radio Manufacturers Association and the Institute of Radio Engineers. The JTAC reports to the two boards of directors who have delegated the responsibility to Doctor B. E. Shackelford, president of the IRE, and to Doctor W. R. G. Baker, director of engineering of the RMA as direct contacts.

Philip F. Siling, chief engineer of the RCA Frequency Bureau, of Washington, was appointed first chairman of the new committee as a representative of IRE. The vice-chairman is Donald G. Fink, (M '45) editor of *Electronics*, New York, N. Y., who is a representative of RMA.

The other six members of the 8-man committee are: Doctor Ralph Brown (F '41) of Bell Telephone Laboratories, Murray Hill, N. J.; Melville Eastham (F '46) of General Radio Company, Cambridge, Mass.; John V. L. Hogan (M '20) of Interstate Broadcasting Company, Inc., New York, N. Y.; E. K. Jett, a former commissioner of the FCC and now director of the *Baltimore Sun's* radio and television operations, Baltimore, Md.; Haraden Pratt (F '37) of Mackay Radio, New York, N. Y.; and David B. Smith (A '35) of Philco Corporation, Philadelphia, Pa. Lawrence G. Cumming, IRE technical secretary, is nonmember secretary of the committee.

One of the first tasks of the committee is to gather authoritative information on the availability of equipment and propagation characteristics in the ultrahigh frequencies in preparation for a television hearing (docket 8976) called by the FCC to start September 20, 1948. The issues to be considered are as follows:

1. To obtain full information concerning interference to the reception of television stations operating on channels 2 through 13 resulting from adjacent channel operation of other services, from harmonic radiations, and from man-made noise.

2. To receive such additional data as may be available since the close of previous hearings (dockets 6651 and 7896) concerning the propagation characteristics of the band 475 to 890 megacycles.

3. To obtain full information concerning the state of development of transmitting and receiving equipment for either monochrome or color television broadcasting, or both, capable of operating in the band 475 to 890 megacycles.

4. To obtain full information concerning any proposals for the utilization of the band 475 to 890 megacycles or any part thereof, for television broadcasting and the standards to be proposed therefor.

At the request of JTAC, members of the commission staff have prepared the following list of detailed questions:

1. What is the present state of development of equipment in the band 470 to 890 megacycles, in regard to

(*a*). Transmitters, tubes, and components?

(*b*). Receivers and components?

(*c*). Antennas, transmission lines, and related equipment for transmission and reception?

2. How much experimental work has been undertaken in television systems in this band, with respect to field operation (transmitter hours operated, number and distribution of receivers, and propagation tests) and laboratory work (development of receivers, transmitters, and tubes)?

3. What consideration has been given to the costs of television systems for this band, particularly to the reduction of receiver costs, and the transfer of cost burdens to the transmitter?

4. What areas of service might be expected in this band, based on the following assumptions:

(*a*). A particular system, using one of the following typical bandwidths: 6 megacycles, 13 megacycles, 20 megacycles.

(*b*). Radiated power, available now and expected to be available, say, ten years in the future.

(*c*). Receiver sensitivity.

(*d*). At each of the following typical frequencies: 475 megacycles, 600 megacycles, and 890 megacycles.

5. What cochannel and adjacent-channel separations would be appropriate under the assumptions made in item 4?

6. How many channels would be available in the band 475–890 megacycles on the assumptions of item 4, and how might they be allocated among the 140 metropolitan districts of the United States?

To assist the committee in obtaining the widest possible contact with sources of information in the industry, any information related to these questions should be communicated directly to the secretary of the Joint Technical Advisory Committee, L. G. Cumming, Institute of Radio Engineers, 1 East 79 Street, New York 21, New York.

Synthetic Mica Developed With Natural Mica Characteristics

A synthetic mica has been produced for the first time with the desirable characteristics of natural mica, strategic stockpile material used in electronic equipment. The synthetic material is being produced on a pilot-plant scale under a co-ordinated research program sponsored by the Office of Naval Research, the Army Signal Corps, and the Navy Bureau of Ships.

Production of synthetic mica on a commercial scale will make the United States independent of foreign sources for the strategic mineral that is used widely in Army and Navy communication and electric equipment. Although natural mica is found in several parts of this country and despite a government subsidy of $6 a pound, only 15 per cent of the amount needed in the critical war years of 1943 and 1944 was produced here. The government has considered the mica supply sufficiently acute to designate needed grades of the mineral as class A strategic materials under the recently enacted Stockpiling Act.

Known as fluorine-phlogopite mica, the synthetic form now being produced has the desirable characteristics of natural mica, including perfect cleavage into thin sheets, good electrical and mechanical properties, and chemical stablity. It is expected to replace the muscovite and phlogopite forms of natural mica, silicate minerals which the United States has imported in large quantities for use as insulation in electric machinery and as a dielectric in electronic circuits.

Also inherent in the new mica synthesis process is the possibility that further research may reveal ways of directly fabricating mica components, which would eliminate the time consuming and laborious tasks of sorting, grading, splitting, and trimming natural mica.

Government-sponsored research on mica synthesis was initiated under a Signal Corps contract at the Colorado School of Mines on June 15, 1946. The Interior Department's Bureau of Mines Electrotechnical Laboratory, at Norris, Tenn., began synthetic mica pilot-plant work on September 1, 1947, under an Office of Naval Research contract. The contract was negotiated at the request of the Bureau of Ships, which stimulated the development of synthetic mica for the Navy. Funds are supplied by the Navy and the Army Signal Corps. The program is being co-ordinated by a committee consisting of two Navy and two Army Signal Corps members.

To carry the program forward, the Office of Naval Research has assembled some of the most experienced engineers and scientists available in the field of mica synthesis. The Owens-Corning-Fiberglas Corporation has been retained under a consulting contract, which makes available all of the data and patents acquired by that company and the Corning Glass Works in two years of investigation of mica synthesis, during 1945–46.

Because of the widespread interest in use of mica among the electrical fabricators of the country, the Office of Naval Research is developing a procedure for prompt and wide dissemination of the results of the development work at the Bureau of Mines Electrotechnical Laboratory to the electrical, electronics, and other industries interested in using synthetic mica. Organizations interested in the possible application of flourine-phlogopite mica are invited to write the Office of Naval Research, Department of the Navy, for further details.

Atomic Research Given High Priority in Britain

Atomic research has been given priority over any other national project in Great Britain according to Sir John D. Cockcroft, director of the Harwell research plant in England. On July 20, 1948, the British government for the first time permitted reporters of all nations to visit the Harwell atomic research plant.

Sir John refused to discuss Great Britain's capacity to produce the atomic bomb, however, in referring to the industrial applications of nuclear power, he said:

> No serious person working in the field believes that nuclear energy will make any contribution to world power during the next decade. It is probable, however, that a number of pilot plants will be built to allow all these problems to be investigated and solved. That is one of the jobs of Harwell.

Harwell, a permanent Royal Air Force field during the war, was taken over by the officially titled Ministry of Supply Atomic Energy Research Establishment in April 1946. The core of current research now taking place is contained in four permanent hangars which have been converted into machine and work shops and which house the plant's two piles, "Gleep" (graphite low-energy experimental pile) designed to develop about 100 kw of heat, and "Bepo" (British experimental pile), designed to develop about 6,000 kw of heat in its uranium metal bars. The cyclotron under construction will consist of a 700-ton magnet, with poles 110 inches in diameter. Although smaller than the cyclotron in use at the University of California, it will be, when completed, the largest of four in operation in Britain.

Materials Work Emphasized at ASTM Annual Meeting

With more than 135 technical papers and reports of the Society's committees, some 360 committee meetings, and an extensive exhibit of testing and research apparatus and laboratory equipment, the 51st annual meeting of the American Society for Testing Materials again emphasized the importance of work in materials.

As a result of recommendations by the society's committees which are responsible for initiating and carrying through work on specifications and tests for materials, there were 52 new tentative specifications and tests approved and about 70 existing tentatives are to be adopted as standard subject to society letter ballot during the summer.

Total registration for the week was something over 1,775, compared with the figures of 1,835 for the 1946 meeting in Buffalo, and 1,786 for the annual meeting in Atlantic City in 1947, a year ago.

An audience of 250 attended the roundtable discussion on ultra-sonic testing in which leading authorities participated. There were two prepared discussions giving fundamental background, and a number of others who use these interesting methods of determining the soundness of metal covered the practical applications. Also of interest to the metallurgist was the symposium on metallography in color with latest developments covered in several papers. It is hoped these will be published later in the year.

The symposium on magnetic testing in two sessions with nine papers brought up to date the art and science in this field. The symposium described some of the problems encountered and the methods that are used to overcome them. Other symposiums and sessions of specific interest in the field of metals covered the deformation of metals as related to forming and service, and effect of temperature of the properties of metals.

The Charles B. Dudley Medal, named after the society's first president, and awarded to the author or authors of a paper in the field of research, was presented to N. L. Mochel, Westinghouse Electric Corporation, and P. R. Toolin, Westinghouse Research Laboratories, for their paper presented in 1947 on "The High-Temperature Fatigue Strength of Several Gas Turbine Alloys." The Richard L. Templin Award, interested in stimulating the development of test methods and apparatus, was given to G. S. Burr, W. J. Gailus, J. O. Silvey (A '40), S. Yurenka, and A. G. H. Dietz, Massachusetts Institute of Technology, for their 1947 paper covering "Universal Plastics Testing Machine." The Sanford E. Thompson Award going to an author of a paper of outstanding merit in the field of concrete and concrete aggregates was awarded to W. C. Hanna, California Portland Cement Company, for his 1947 paper on "Unfavorable Chemical Reactions of Aggregates in Concrete and a Suggested Corrective."

The society's Marburg Lecture, which commemorates the name of the society's first secretary and recognizes his pioneering work in stimulating the presentation and discussion of papers and reports in the field of materials, was delivered by Doctor P. C. Aebersold, Atomic Energy Commission. He covered "Isotopes and Their Application in the Field of Industrial Materials," and stressed the tremendous possibilities of these new materials which are now available for science and industry to use in a wide variety of applications.

Three engineering leaders, long-time and active members of the society, were awarded honorary memberships. They are as follows: Harvey L. Curtis (F '26) formerly principal physicist with the National Bureau of Standards, now retired; Frank H. Jackson, Public Roads Administration, Washington, D. C.; and William B. Price, formerly with the Scoville Manufacturing Company, Waterbury, Conn., retired late in 1947.

National Instrument Conference Scheduled for Philadelphia

A tentative program has been released for the National Instrument Conference which will be held September 13–17, 1948, at Convention Hall, in Philadelphia, Pa. The conference is sponsored by The Instrument Society of America, which this year is being joined by the AIEE, the American Institute of Physics, and the American Society of Mechanical Engineers.

Two AIEE sessions are being planned for inclusion in the 5-day program. On Thursday, September 16, at 2 : 30 p.m., an AIEE session on electronic instruments will be held under the chairmanship of R. Feldt (M '46) of the Allen B. DuMont Laboratories, Inc., Passaic, N. J. Papers presented at this session will include:

"Fail-Safe Operation of Electronic Circuits," G. D. Hanchett, Radio Corporation of America Manufacturing Company, Camden, N. J.

"Cathode-Ray Oscillograph Developments for Laboratory and Production Use," C. Berkley, Allen B. DuMont Laboratories, Inc., Passaic, N. J.

"Oil Film Thickness Indicator for Journal Bearings," M. L. Greenough, National Bureau of Standards, Washington, D. C.

W. R. Clark (M '44) Leeds and Northrup Company, Philadelphia, Pa., will preside at an AIEE session on electronic instruments scheduled for Friday, September 17, at 2 : 30

p.m. Mr. Clark is chairman of the AIEE joint subcommittee on electronic instruments. The following papers will be presented at this session:

"Résumé of AIEE Conference on Electron Tubes for Instrumentation and Industrial Use Held in Philadelphia, March 29 and 30," Chairman W. R. Clark

"A Study of Slide Wire Contact Resistances," W. E. Belcher, Jr., Brown Instrument Company, Philadelphia, Pa.

"Development of Self-Balancing Recorders," A. J. Williams, Jr. (M 45) Leeds and Northrup Company, Philadelphia, Pa.

"Salinity-Temperature-Depth Recorder," A. W. Jacobson (A '41) Bristol Company, Waterbury, Conn.

The technical sessions planned for the third National Instrument Conference promise to be among the finest ever arranged. Prominent authorities in many fields are cooperating to make this part of the conference worth the time of anyone interested in instrumentation.

Surface Reactions Conference Held in Pittsburgh, Pa.

The Pittsburgh International Conference on Surface Reactions was held at the Webster Hall Hotel, Pittsburgh, Pa., June 7–11, 1948. Several informal conferences not scheduled were arranged, and the attendance at these conferences had as large an audience as the announced sessions. Thirty-one papers, representing the present state of research work in surface reactions, were presented.

Including the speakers the attendance was slightly more than 300, representing scientific and technical organizations interested in the field of surface reactions, including oxidation, corrosion, and the nature of protection.

The papers presented have been reproduced in a book of 236 pages, 8½ inches by 11 inches bound in heavy paper cover and followed the general subjects:

1. Theory of liquid phase reactions
2. Theory of oxidation and surface reactions
3. Preparation of surfaces
4. New methods and results
5. Fundamental mechanisms
6. Corrosion and its measurement

Some copies of the book are still available at $10 per copy.

Electrical Developments Subject of Iron and Steel Exposition

The advance program for the Iron and Steel Exposition and Convention indicates that three full half-day technical sessions will be devoted to the discussion of electrical advancements and developments which apply to the iron and steel producing industry.

The opening session of the exposition, which will be held at Cleveland Public Auditorium from September 28 through October 1, 1948, will feature the following papers on electrical subjects: "Air Conditioning of Crane Cabs," R. D. Darrah, Dravo Corporation, Pittsburgh, Pa.; "Some Results of Mercury Arc Rectifier Operations," Frank W. Cramer (M '40) Carnegie-Illinois Steel Corporation, Pittsburgh; "Developments in Electrical Cables for the Steel Industry," E. W. Davis (F '34) Simplex Wire Company, Cambridge, Mass.

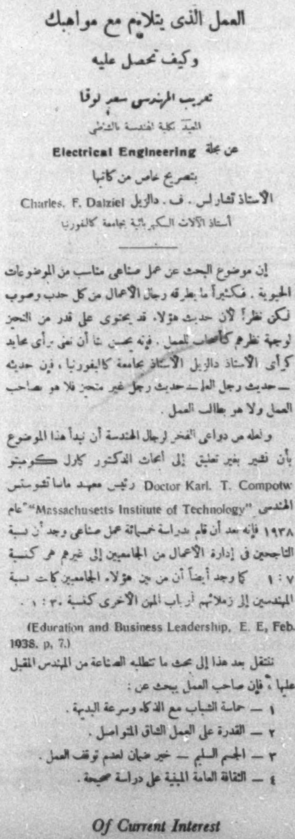
On Wednesday, September 29, the electrical session will include: "Electric Equipment for Rolling Cold Strip at 70 miles Per Hour," W. E. Miller (M '45) General Electric Company, Schenectady, N. Y.; "Review of Runout Table Drives," I. N. Tull, Republic Steel Corporation, Cleveland; "Improved Flying Shear Drives," J. Raymond Erbe, Westinghouse Electric Corporation, Pittsburgh.

The third electrical session is the morning of September 30, featuring papers on: "Magnatorque A-C Crane Control," F. W. Wendelburg and F. M. Blum, Harnischfeger Corporation, Milwaukee, Wis.; "A Network System for Dynamic Lowering Hoist Control," D. L. Pettit, Square D Company, Milwaukee; "Designing the Proper Equipment for Extracting Ingots from their Molds," H. W. Ball, Morgan Engineering Company, Alliance, Ohio.

EE Article Reprinted in Egyptian Magazine

That articles appearing in *ELECTRICAL ENGINEERING* reach a wide audience is indicated by a publication recently received from Saad L. Mikhail (A '00). It is the December 1947 issue of the *Engineers Magazine*, a monthly publication published in Cairo, Egypt, in Arabic, by a Mr. Ibrahim A. Osman, lecturer in the faculty of engineering, Fouad 1 University, Cairo, Egypt.

The issue contains a reprint of "Suggestions on Seeking Employment" by Professor Charles F. Dalziel, which appeared in *ELECTRICAL ENGINEERING* some time ago (*EE May '39, pp 202–5*). The translation was done by Mr. Mikhail who is demonstrator of electrical engineering, Farouk 1 University, Alexandria, Egypt. Shown here is a reproduction of the leading part of the article as it appeared in the *Engineers Magazine.*



العمل الذى يتلاءم مع مواهبك
وكيف تحصل عليه

تعريب المهندس سعد لوقا
المعيد بكلية الهندسة بالشاطبى

عن مجلة **Electrical Engineering**
بتصريح خاص من كاتبها
الأستاذ تشارلس . ف . دالزيل Charles. F. Dalziel
أستاذ الآلات الكهربائية بجامعة كاليفورنيا

إن موضوع البحث عن عمل صناعى مناسب من الموضوعات الحيوية . فكثيراً ما يطرقه رجال الأعمال من كل حدب وصوب لكن نظراً لأن حديث هؤلاء قد يحتوى على قدر من التحيز لوجهة نظرهم كأصحاب للعمل . فإنه يحسن بنا أن نعنى برأى محايد كرأى الأستاذ دالزيل الأستاذ بجامعة كاليفورنيا ، فإن حديثه — حديث رجل العلم — حديث رجل غير متحيز فلا هو صاحب العمل ولا هو طالب العمل .

ولعله من دواعى الفخر لرجال الهندسة أن نبدأ هذا الموضوع بأن نشير بغير تعليق إلى أبحاث الدكتور كارل كومبتو Doctor Karl. T. Compotw رئيس معهد ماساتشوستس الهندسى "Massachusetts Institute of Technology" عام ١٩٣٨ فإنه بعد أن قام بدراسة خمسمائة عمل صناعى وجد أن نسبة الناجحين فى إدارة الأعمال من الجامعيين إلى غيرهم هى كنسبة ١ : ٧ كما وجد أيضاً أن من بين هؤلاء الجامعيين كانت نسبة المهندسين إلى زملائهم أرباب المهن الأخرى كنسبة ٣٠ : ١ .

(Education and Business Leadership, E. E, Feb. 1938. p, 7.)

ننتقل بعد هذا إلى بحث ما تتطلبه الصناعة من المهندس المقبل عليها ، فإن صاحب العمل يبحث عن :

١ — حماسة الشباب مع الذكاء وسرعة البديهة .
٢ — القدرة على العمل الشاق المتواصل .
٣ — الجسم السليم — خير ضمان لعدم توقف العمل .
٤ — الثقافة العامة المبنية على دراسة صحيحة .

35th Annual Convention Held by Electroplaters

The 35th annual convention of the American Electroplaters' Society was held in Atlantic City, N. J., June 28–July 1, 1948. Attracting more than 1,200 registrants, the convention used the Ambassador Hotel for its headquarters and the ballroom of Convention Hall for its technical sessions and business meetings. Sponsored concurrently by the society, the Industrial Finishing Exposition was held on the main floor of Convention Hall. The Newark Branch of the American Electroplaters' Society was host for the entire convention, which was under the general chairmanship of Horace H. Smith.

Papers read at the technical sessions covered the scientific, engineering, and economic aspects of electroplating and metal finishing. Presented by a series of well-known authors the 20 papers were well received by the assembly and discussed enthusiastically. The entire proceedings of the technical sessions including the discussions will be made available as a bound volume by the society some time after October.

Society honors were received by several authors. The Herminie Dorothea Proctor Award of $100 was awarded to Doctor Abner Brenner and Seymour Senderoff of the National Bureau of Standards for their paper, "The Helical Contractometer, a New Instrument for the Measurement of Stress in Electrodeposits." R. H. Cahan and C. E. McKinnon of E. I. duPont deNemours and Company were given the Founders Gold Medal for their paper, "Diaphragm Tanks to Eliminate Roughness in Copper Plating."

Awards also were given to authors of articles appearing in the Society journal *Plating* during 1947–48. The Society's Award of $50 went to C. F. Nixon of Fisher Body—Ternstedt Division, General Motors Corporation and Doctor R. C. Olsen of Pacific Lutheran College for their article, "Notes on Nickel and Chromium Plating," and the A.E.S. Gold Medal to E. J. Roehl of Thomas Steel Company for his article, "Mechanical Properties of Nickel Deposits."

A. F. Davis Welding Awards. The American Welding Society presented the cash prizes totalling $700 in the 1948 A. F. Davis Undergraduate Welding Award program during ceremonies on June 3, 1948 at Ohio State University, Columbus, Ohio, and at the Rose Polytechnic Institute, Terre Haute, Ind.

Robert Baysinger, a junior in welding engineering at Ohio State University, received the first prize of $200 for his paper entitled, "A Brief Review of Failures in Welded Vessels," and the *Ohio State Engineer*, magazine in which the winning article was published, received a similar award of $200. Mark J. Orelup, a junior in electrical engineering at Rose Polytechnic Institute, was presented the second prize award of $150 for "Spot Welding of Carbon Steels." The article appeared in the November 1947 issue of the *Rose Technic*, which also received a $150 award.

New IES Officers Announced. The Illuminating Engineering Society has elected Lee E. Tayler of the Detroit Edison Company, Detroit, Mich., as president of the society for a term of one year, according to a recent announcement. He will take office during the IES National Technical Conference to be held in Boston, Mass., September 20–24, 1948. Other officers elected to serve with Mr. Tayler are: A. H. Manwaring (M '46) Philadelphia Electrical and Manufacturing Company, Philadelphia, Pa., *general secretary;* E. M. Strong (M '40) Cornell University, Ithaca, N. Y., *treasurer;* Walter Sturrock, General Electric Company, Cleveland, Ohio, *vice-president;* Myrtle Fahsbender, Westinghouse Electric Corporation, Bloomfield, N. J., *director;* Hoyt Steele (A '44) Benjamin Electric Manufacturing Company, Des Plaines, Ill., *director.*

ASTM Announces New Officers. Richard L. Templin, assistant director of research and chief engineer of tests, Aluminum Company of American, New Kensington, Pa., has been elected president of the American Society for Testing Materials for a term of one year. He has been a member of ASTM since 1917. L. J. Markwardt, assistant director, United States Forest Products Laboratory, Madison, Wis., was elected vice-president. Also elected were the following members of the board of directors: Leslie C. Beard, Jr., chemist and assistant director of laboratories, Socony-Vacuum Oil Company, Inc., New York, N. Y.; Simon Collier, director of quality, Johns-Manville Corporation, New York, N. Y.; Theodore P. Dresser, Jr., chief engineer, Abbot A. Hanks, Inc., San Francisco, Calif.; Howard K. Nason, associate director, central research department, Monsanto Chemical Company, Dayton, Ohio; and Edgar W. Fasig, general superintendent, Lowe Brothers Company, Dayton.

Veterans Ask Technical Magazines. According to the Engineers' Society of Milwaukee, men in the Veterans' hospitals have expressed a sincere desire for magazines of a technical nature. They have considerable material of the so-called "popular" class, but little technical literature is available to them. ESM through its library committee, has made an appeal through the local press to all who could contribute journals of the various societies, covering engineering, economics, political science, physics, chemistry, factory management, and so forth, in fact any material of a scientific or technical classification. The response from this publicity was extremely gratifying, and it has been suggested that this appeal should be made on a national basis, in the hope that various technical societies, veterans' organizations, and service clubs, would co-operate and conduct a local campaign of their own for the Veterans' Hospital in their own vicinity,

M. J. Kelly Named Chairman of New Navigation Committee

Doctor M. J. Kelly (F '31) executive vice-president of Bell Telephone Laboratories, Inc., New York, N. Y., has been named chairman of the newly constituted Committee on Navigation, according to a recent announcement of Doctor Vannevar Bush (F '24) chairman of the Research and Development Board, Washington, D. C.

The new committee was formed after a 6-month study by the Research and Development Board of over-all problems related to land, marine, and air navigation. The committee will have cognizance of research and development aspects of devices, systems, and techniques applicable to problems of land, marine, and air navigation and traffic control. The new group will work closely with the Air Navigation Development Board, recently established jointly by the Secretaries of Defense and Commerce, also in implementation of the board's study, to proceed with developing a single basic system of air navigation and traffic control that will meet the needs of both civilian and military users.

Doctor Kelly, who had participated actively in the Research and Development Board's 6-month study, has been with the Bell Telephone Laboratories since 1918. A complete biographical sketch of the new chairman appears in this issue (*page 916*).

ASEE Elects Officers. The election of Clement J. Freund, dean of the college of engineering at the University of Detroit, as president of the American Society for Engineering Education for the year 1948–49 was announced at the annual convention of the society held at the University of Texas, Austin, Texas, June 18, 1948. The convention was attended by 1,100 engineering educators and administrators of engineering colleges. Thorndike Saville, dean of the college of engineering at New York University, was elected vice-president; F. M. Dawson, dean of the college of engineering at the State University of Iowa, was re-elected vice-president of the society and president of the Engineering College Research Council; James S. Thompson, vice-chairman of the board of directors of McGraw-Hill Book Company, was elected treasurer.

Technical Group Names Egloff. Doctor Gustav Egloff, director of research, Universal Oil Products Company, has been re-elected president of the Chicago Technical Societies Council. Other officers for the 1948–1949 term include: Doctor Clyde A. Crowley, *executive vice-president;* Lewis A. Bain, Robert

Huge Casting for Turbine Generator

Dwarfed by a huge casting at the General Electric Company's Schenectady, N. Y., turbine plant, a workman fits easily inside a bearing housing as he inspects the casting's machined surfaces. When this casting has been assembled as part of the completed turbine-generator set, the bearing will support one end of a whirling 42-ton turbine rotor. The set is the second of two 100,000-kw rated capacity turbine generators built at Schenectady for the Tidd Station of the Ohio Power Company, Brilliant, Ohio, of the American Gas and Electric Company's central system

H. Bacon, Doctor Herman S. Bloch, and Paul S. Smith, *vice-presidents;* R. T. Van Niman, *corresponding secretary;* William Kucinski, *recording secretary;* and Frederic E. Oakhill (M '46) *treasurer.* New directors are: Doctor Johan A. Bjorksten, W. Fred Dolke, and Clarence M. Sieben. Incumbent directors are: Kenneth H. Hobbie, John E. Ott, Jean O. Reinecke, and Doctor H. A. Wagner.

Television Congress in Paris. With "The Relations Between Television and the Cinema" as its theme, a Congress on Television, organized by the Société des Radioélectriciens, will be held in Paris, France, October 25–30, 1948. A number of sessions also will be devoted to general problems concerning television such as tubes of emission and amplification with large strip bands, transmission of television on cable and by Hertzian relays, propagation, signals of synchronization, and problems of exploitation. In addition the program will include various technical inspection trips and demonstrations, as well as a sightseeing trip and a banquet on Thursday, October 28.

OTS Issues Abstracts of Enemy-Owned US Patents

A compilation of abstracts of 358 United States patents formerly owned by nationals of foreign countries and seized by the Department of Justice, Office of Alien Property, since November 1945, is now on sale by the Office of Technical Services, Department of Commerce. Most of the patents are available for licensing to American firms by the Office of Alien Property on a royalty-free nonexclusive basis for the remaining life of the patents. The compilation is one of several groups of patents that will be issued from time to time in co-operation with the Office of Alien Property, and covers patents not included in the published abstracts distributed by that office.

The abstracted patents in the compilation are classified into broad groups such as chemicals and allied products; electric machinery, equipment, and supplies; and metals and metal products. Refrigeration, automotive, aeronautics, textiles, paper-making, photography, food-processing, and electronics are among the fields covered, and specific items of interest include an electric motor starting device, a mercury-containing-storage battery, a compensating arrangement for television tubes, and a hydraulic transmission gear.

Copies of the compilation (Report *PB-88841*, "List of Vested Patents Available from Office of Alien Property," 85 pages) sell for 14. Orders should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., accompanied by check or money order payable to the Treasurer of the United States. Copies of the patents may be examined in Room 1325, Commerce Building, Washington, D. C.

A leaflet called "Index and Guide to Enemy Patents Vested in the Attorney General as of January 1947," which contains general information about the availability of enemy patents, is available free-of-charge from either OTS or the Alien Property Custodian. All communications concerning the licensing of enemy patents should be addressed to the Office of Alien Property, Department of Justice, Washington 25, D. C. Copies of individual patents may be purchased only from the Commissioner of Patents, United States Patent Office, Washington 25, D. C., for 25¢ each. Orders must specify the serial number of each patent desired.

IRE Fall Meeting. The 1948 Rochester fall meeting of members of the Institute of Radio Engineers and the Radio Manufacturers Association engineering department will be held November 8, 9, and 10 at the Sheraton Hotel, Rochester, N. Y., according to a recent announcement. The meeting will be sponsored by the Rochester fall meeting committee and will mark the 20th anniversary of the meeting. Officers of the committee include H. J. Klumb (A '16) of the Rochester Gas and Electric Corporation and O. L. Angevine (M '43) of the Rochester Engineering Society.

Engineering Foundation to Sponsor 14 Projects

Fourteen research projects will be sponsored by the Engineering Foundation for the year beginning in October 1948. Grants have been recommended for the continuation of 12 of the past year's 17 projects, and for the support of two new ones.

The projects will be concerned with studies in such varied fields as hydraulics, metal cutting, alloys of iron, properties of gases and gas mixtures, riveted and bolted structural joints, reinforced concrete, welding, and properties of metals at different temperatures.

In selecting projects to be supported, preference was given to those of the most fundamental nature which would not be undertaken by an industrial research organization. Where projects are of interest to a group of industries, the foundation provides a limited financial support and sponsorship intended to enable the principal support of the project to be secured from interested industries and other sources.

Research is carried on in a number of universities and some engineering plants in co-operation with the foundation's engineering founder societies: the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the AIEE.

EJC Offers Truman Aid in Science Appointments

Anticipating enactment of the legislation to establish a National Science Foundation, Engineers Joint Council has presented to President Truman a list of eminent engineers from which appointments to the membership of the foundation might be made. It is suggested in the national science legislation that the President obtain the advice of scientific and educational institutions when making appointments.

As many more scientists engaged in research are drawn from the field of engineering than from any other branch, EJC pointed out that it is appropriate that engineering be represented substantially on the foundation.

Looking forward to the time when appointments will be made, the constituent societies of Engineers Joint Council, as well as the American Society for Engineering Education, prepared lists of prominent engineers deemed to be qualified for service. These lists were placed before the EJC committee on science legislation which chose 23 as being the most appropriate candidates. In addition to those specifically representing the several societies, five of the men included were selected as engineers eminent in public affairs.

On June 4, a delegation of six headed by Doctor Boris A. Bakhmeteff of the American Society of Civil Engineers met with Doctor John R. Steelman, advisor to President Truman, at the White House, presented the list of candidates, and discussed reasons why engineering should be well represented on the foundation. The group met with a cordial reception and assurance was received that full consideration will be given to the engineers' recommendations.

Electric Equipment Committee Accorded NSC Sectional Status

The electric equipment committee of the National Safety Council, formed last October, has been accorded full sectional status as one of the 24 industrial sections of the council, according to a recent announcement.

The action was taken at a recent meeting of the council's board of directors upon recommendation of the industrial conference representing all sections. The glass and ceramics committee and the printing and publishing committee also became sections in the official move, 33 years after the first council sections were formed in 1915.

Sectional status for the industry will permit development of posters, films, and technical publications geared to the special needs of the industry. Emphasis will be placed on the problems of women in industry, high-frequency hazards, electrical testing, soldering, and other occupational disease hazards including X ray, radar, television, and frequency modulation.

Technical projects already begun include a study of the hazards of beryllium, cathode-ray tubes, and electric welding. An engineering committee has been formed to guide this work, and two sessions are planned by the section at this year's National Safety Congress and Exposition, to be held October 18–22 in Chicago, Ill.

Quality Control Society Elects. According to a recent announcement, the American Society for Quality Control has elected Ralph E. Wareham of New York, N. Y., as president for a one-year term. Mr. Wareham is vice-president and a director of National Photocolor Corporation of New York. George D. Edwards (M '26) of the Bell Telephone System, New York, N. Y., is retiring president of the Society. Other officers elected were: *Vice-president*—W. R. Weaver, Republic Steel Corporation, Cleveland, Ohio; *executive secretary*—S. Collier, Johns Manville Corporation, New York, N. Y.; *treasurer*—A. L. Davis, Rochester Institute of Technology, Rochester, N. Y.

Armstrong Medal to Ballantine. In accordance with the Radio Club of America's announcement last December of the posthumous award of the Armstrong Medal to the late Stuart Ballantine, the medal recently was presented to Mrs. Stuart Ballantine by Major Edwin H. Armstrong. Mr. Ballantine, a pioneer in radio, developed the loop compass and radio direction finder during World War I and, later, the principle of negative feedback and of automatic volume control. He also was responsible for developing the theory of the vertical antenna and its low angle radiation, as well as much important work in acoustics. The citation accompanying the medal reads: "The Armstrong Medal, of the Radio Club of America is awarded to Charles Stuart Ballantine for outstanding contributions to the art."

Iowa State Honors Graduates. At its 77th annual commencement in June, the Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa, conferred special honors upon two of its distinguished graduates and eminent engineers. The degree of doctor of engineering, honoris causa, was granted to Anson Marston, dean emeritus of the division of engineering. The Marston Medal, established in 1938 through the inspiration and generosity of Dean Marston, was awarded to Roy W. Crum, an engineering alumus of the Iowa State College, in recognition of outstanding achievement in engineering.

REA Expansion Creates Vacancies for Engineers

Because of the great expansion authorized by the Congress in the Rural Electrification Administration program, the agency is experiencing difficulty in recruiting qualified engineers to meet its needs.

Currently, the REA is trying to fill vacancies with starting salaries of $3,727, $4,479, and $5,232. Basic requirement is a degree in electrical engineering (or its equivalent in practical experience) plus at least a year of work in the field of electricity, half of which must be in connection with distribution. The higher grades require additional years of experience. Most of the positions are in the field, involving almost continuous travel within a state. Travellers are allowed five cents a mile for use of personal automobiles and 16 a day for subsistance. As vacancies occur in the future in higher-salaried positions, it will be the general policy to fill them by promotion from within the organization.

Inquiries should be addressed to John W. Asher, Jr., Chief, Personnel Division, Rural Electrification Administration, United States Department of Agriculture, Washington 25, D. C.

Commonwealth Edison Companies Invest in Atomic Research

Interest in the development of atomic energy has led the Commonwealth Edison group of companies to invest $100,000 in the University of Chicago's Institute for Nuclear Studies. The Utilities Research Commission, representing the Edison group, has become a member of the institute. The commission is the research agency for the Commonwealth Edison Company, Public Service Company of Northern Illinois, Western United Gas and Electric Company, and Illinois Northern Utilities Company. It represents the 12th organization to support the three institutes at the university now conducting a $12,000,000 program of atomic and metal research.

As a member of the institute the commission will be able to keep abreast of atomic developments through association with outstanding scientists at the university. In addition, engineers from the commission will join those from other sponsoring organizations at quarterly meetings at the university.

Other industries participating in the work of the university's Institute for Nuclear Studies, Institute of Metals, and Institute of Radiobiology and Bipophysics include:

The United States Steel Corporation, Sun Oil Company, Shell Oil Company, Inland Steel Company, Standard Oil Company of Indiana, Aluminum Company of America, Westinghouse Electric Corporation, Pittsburgh Plate Glass Company, Standard Oil Development Company of New Jersey, Celanese Corporation of America, and the Beech-Nut Packing Company.

RMA Standards Keep Pace with Technical Developments

With the aim of keeping abreast of wartime and more recent technical developments in the radio and electronics industry, the Radio Manufacturing Association engineering department has issued 21 recommended engineering standards during the past year and has two score more in progress.

A total of 174 committees, comprising hundreds of the industry's foremost engineers, are engaged in the gigantic study. More than 200 meetings were held during the past fiscal year and 379 reports were published and distributed to RMA members. Doctor A. R. G. Baker, (M '41) vice-president of General Electric Co. in charge of the electronics department at Syracuse, N. Y., is director of the RMA engineering department.

While many of the RMA standards issued and under consideration have to do with component parts, rather than the completed equipment, their voluntary adoption by the radio industry has expedited the adaptation of technical developments to commercial use with resulting benefits to the public.

Most of the 21 standards issued during the past year were new but a few were revisions of prewar standards. Four of them were subsequently reprinted as joint standards of RMA and the National Electrical Manufacturers Association as they were developed by the Joint Electronic Tube Engineering Council.

The RMA engineering department also carried on extensive tube type designations and registrations for the radio industry during the year. A total of 154 tube type designations were registered, and 197 were reserved.

Following is the complete list of the 21 recommended standards published during the year:

Disk Home Recording

Color Coding

Intermediate Frequencies

Antenna-to-Set Transmission Line for Television Receivers

Chassis Pickup of Vehicular Receivers

Tube-Type Designations

Class *A* Variable Air Capacitors

Ceramic Dielectric Capacitors

Dry-Type Power Transformers for Radio Transmitters

Transmission Lines for Frequency Modulation Broadcast Transmitters (88–108 megacycles per second)

Drive Pulleys

Recommended Standard for Export Receivers

Measurement of Direct Interelectrode Capacitances

Electrical Performance Standards for Television Broadcast Transmitters Channels 1–13 (44 megacycles–216 megacycles)

Amplifiers

Electrical Performance Standards for Standard Broadcast Transmitters

Audio Facilites for Radiobroadcasting Systems

Dimensional Characteristics of Gaskets for Water-Cooled Transmitting Tubes

Designation System for Receiving Tubes

Vibrating Interrupters and Rectifiers for Auto-Frequency 115 Cycles

455-Kc Intermediate Frequency Transformer

Western Society Elects Officers. Verne O. McClurg, partner in the Chicago archi-

Future Meetings of Other Societies

American Chemical Society. Fifth National Chemical Exposition and National Industrial Chemical Conference, October 12–16, 1948, Chicago, Ill.

American Oil Chemist's Society. Fall meeting, November 15–17, 1948, Pennsylvania Hotel, New York, N. Y.

American Radio Relay League (ARRL) Convention. September 4–6, 1948, Milwaukee Auditorium, Milwaukee, Wis.

American Society of Civil Engineers. Fall meeting, October 13–15, 1948, Boston, Mass.

American Society of Refrigerating Engineers. 44th annual meeting, December 5–8, 1948, Washington, D. C.

Association of Iron and Steel Engineers. Iron and Steel Exposition, September 28–October 1, 1948, Cleveland, Ohio.

Conference on Research Administration. September 13–15, 1948, Pennsylvania State College, State College, Pa.

FM Association. Annual convention, October 11–12, 1948, Sheraton Hotel, Chicago, Ill.

Illuminating Engineering Society. National technical conference, September 20–24, 1948, Boston, Mass.

Institute of Radio Engineers. Pacific Coast convention, September 30–October 2, 1948, Los Angeles, Calif.

Instrument Society of America. Third instrument conference and exhibit, September 13–17, 1948, Philadelphia, Pa.

National Electrical Manufacturers Association. November 8–13, 1948, Atlantic City, N. J.

National Electronics Conference. November 4–6, 1948, Edgewater Beach Hotel, Chicago, Ill.

National Exposition of Power and Mechanical Engineering. November 29–December 4, 1948, Grand Central Palace, New York, N. Y.

National Plastic Exposition. September 27–October 2, 1948, Grand Central Palace, New York, N. Y.

National Research Council's Conference on Electrical Insulation. October 27–29, 1948, at the National Bureau of Standards, Washington, D. C.

National Television and Electrical Living Show. September 18–26, 1948, Chicago Coliseum, Chicago, Ill.

Porcelain Enamel Institute. Tenth annual forum, October 13–15, 1948, Urbana, Ill.

Training Conference on Industrial Experimentation. September 14–18, 1948, Columbia University School of Engineering, New York, N. Y.

tectural and engineering firm of Mundie, Jensen and McClurg, has been installed as president of the Western Society of Engineers succeeding William V. Kahler (F '46) vice-president of the Illinois Bell Telephone Company. Other officers are Gustav Egloff, research director of the Universal Oil Products Company, first vice-president; H. P. Sedwick (M '32) vice-president of the Public Service Company of Northern Illinois, second vice-president; M. P. Vore, Jr., secretary and treasurer of the Republic Flow Meters Company, treasurer. Newly-elected trustees are Wilfred Sykes (F '14) president of Inland Steel Company, and Fred T. Whiting (M '44) vice-president of Westinghouse Electric Corporation.

James M. Todd of New Orleans Nominated as ASME President

James M. Todd (F '45) New Orelans, La., consulting engineer, has been nominated as the next president of The American Society of Mechanical Engineers. His name heads a slate of new officers, including several regional vice-presidents and directors-at-large, submitted by the nominating committee. Nomination is tantamount to election since only one name is presented for each office.

Formal election will take place in the fall by letter ballot of the membership, which totals more than 25,000 engineers throughout the United States. The 1948–49 term will begin at the end of the annual meeting next December.

Mr. Todd, who will succeed E. G. Bailey of New York as president of the engineering society, is in private practice as a consulting mechanical and electrical engineer in New Orleans. Born in Franklin, La., in 1896, he was graduated from Tulane University, New Orleans, in 1918 with the degree of bachelor of engineering, and in 1930 received the degree of mechanical engineer.

Previously he held offices as manager and as vice-president of the ASME, and served on many of its important committees. He became a Fellow of the society in 1944.

Lincoln Foundation Announces Recipients of Scholarships

Awards of $1,000 to the University of Cincinnati, $500 to the University of Minnesota, and $250 to Iowa State College were announced today by The James F. Lincoln Arc Welding Foundation. These awards are to be used for providing scholarships in each school.

The awards represent top honors in the foundation's Annual Engineering Undergraduate Award and Scholarship Program in which awards are given to engineering undergraduates for the preparation of papers on arc welding and its uses. The scholarship funds are awarded to the schools in which the authors of the three best papers were registered and duplicate similar cash awards to each author. Papers were submitted by students from 46 different engineering colleges in all parts of the country.

The paper, "Standardized Welded Building Structures for Railroads," received the first award of $1,000 for Alan R. Cripe of the University of Cincinnati. The paper, "Arc Welded Design as Applied to a Combination Hay Buck-Stacker," written by William David McCoy, undergraduate in the University of Minnesota, received the second award of $500. The third main award went to William W. Robinson of Iowa State College as author of the paper, "Vises Fabricated by Arc Welding Versus Cast Vises."

In addition to these, smaller awards totaling $3,500 were made to 68 undergraduates representing 43 engineering colleges and universities.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

What of Air Safety?

To the Editor:

The article by Robin Beach, entitled "What of Air Safety?" (*EE, May '48, pp 423–9*) incorporates a number of statements and conclusions as well as an explanation for an Eastern Air Lines accident, which are hardly consistent with the facts.

This nation's scheduled air lines were never more concerned with achieving a 100 per cent safety record than they are today. No compromise is being made in this respect. The entire industry is alert to every development that adds up to increased safety—and this includes constructive suggestion by such writers as Mr. Beach.

Unfortunately, Mr. Beach's statements in his listing of "outstanding hazards to safe flying" that "airplane engines still explode in mid-air" and that "baggage and tail compartments still catch fire or explode" indicate that he has failed to keep up with advances or is guilty of misusing the word "explode."

Funk and Wagnall's "New Standard Dictionary" defines "explode" as: "To cause to burst in pieces by force from within; break suddenly and violently in fragments with noise; also, to cause to expand or pass suddenly from a solid to a gaseous state."

Airplane engines do not explode in midair, any more than do automobile power plants explode, and certainly not in accordance with the definition of "explode" as defined in the foregoing. Not for several years have we had any evidence of a baggage or tail compartment exploding or catching fire.

Mr. Beach refers to the propellers tips on commercial airliners moving at speeds of 400–700 miles per hour as approaching sonic value. Proper tip speeds only approach sonic values at maximum engine rpm during the very short take-off period. From then on, propeller operation proceeds at 0.6 to 0.8 value of sonic speed. The operation of propellers with blade tip speed at or near sonic value creates a terrific high pitch noise which is almost unbearable. Furthermore, at such speed the propeller efficiency drops substantially and will not permit to obtain the high efficient values so commonly obtained with transport aircraft propellers.

He also refers to "potential explosion hazards which are developed in the crankcases of the engine." I disagree entirely with this simply because aircraft engine crankcases are ventilated; there is entirely too much lubricating oil whirling around in the form of spray; and the air within the crankcase contains too much burned gases which leak through the piston rings during the explosion stroke.

As for those bearing pittings which the writer calls "spark blemishes," these are really due to overloads and high-frequency vibration. When such bearings are increased in size or their peripheral speed reduced, pitting often disappears.

It is interesting to note that the spark pitting of the rear thrust bearing, cited by the writer, is admitted to be a subject not only theoretical but perhaps speculative. In fact, that might well have been the title of Mr. Beach's article.

Mr. Beach writes: "Thus the so-called 'mysterious' explosions are accounted for which doubtlessly have been responsible for a number of airplane catastrophies." Such "mysterious explosions" are mentioned only in the press and on the radio by inexperienced observers. No trained investigator ever would agree that an explosion ever occurs without a definite cause.

"It is the exception," observes Mr. Beach, "When an example of a crankcase explosion appears as obvious as the one which recently occurred on a 'Constellation' off the coast of Florida." Beneath this statement appears a close-up photo of the aircraft, captioned: "Another fortuitous 'happy landing'—a 'Constellation' in Florida after a crankcase explosion blew off the propeller system."

I am particularly well acquainted with the facts behind this incident for the aircraft described and pictured was operated by Eastern Air Lines. This accident had absolutely nothing to do with an engine crankcase failure. The front nose section broke because of the excessive propeller unbalance due to the loss of a propeller blade tip, or a larger portion of such blade. Therefore, the damage which occurred to the engine was *subsequent* to the propeller failure and did not cause the accident. No engine can be designed to stand the propeller unbalance caused by the loss of a blade tip at cruising rpm.

Still referring to the Florida incident, the writer observes that "such crankcase explosions are a constant threat to safe flying . . . It is an interesting speculation that more catastrophies from this source have not occurred." Let me repeat that in the case of the Florida incident, there was no crankcase explosion.

Mr. Beach writes that "another strange and dangerous behavior of static electricity on high-speed commercial transports exhibits itself in melting holes in the aluminum airfoils near the wing and stabilizer tips." The holes often found in the wing and tail surface trailing edges after an airplane has flown through an electrical disturbance have, to my knowledge, never caused an aircraft accident.

As for his statement that "The failures and blowouts of tires when airplanes land also reap their harvests of crashes and holocausts," I cannot recall of any "holocausts" caused by this type of mechanical difficulty. On the other hand, there is ample proof to conclude that these failures are caused by the sudden spin-up loads caused when accelerating the landing gear wheels from a static condition to a rotational speed corresponding to the contact speed of the tire in the runway.

We are not adverse to criticism, as it is only by constructive criticism that the air transport industry has so rapidly progressed, but any criticism to be of value *must* be based on facts, not supposition or speculation.

CHARLES FROESCH

(Chief engineer, Eastern Air Lines, New York, N. Y.)

To the Editor:

Having received a widespread response of enthusiastic comments on the pioneer treatise covering the gamut of electrostatic hazards on aircraft in my recent article on "What of Air Safety," I also welcome the letter by Mr. Froesch, taking issue with my "statements and conclusions," as it affords me the privilege of amplifying certain parts of the article.

Among some air line operators, as well as personnel of national air commands, there exists either a politic taboo against the use of the phrase "electrostatic fire and explosion hazards" or a shocking dearth of understanding on this vital subject. The public mention of the phrase apparently implies that its daring user is a condemned heretic. I enjoy this distinction as a reward for my contributions to air safety.

The situation is suggestive of the "dark ages" when, less than 500 years ago, he who disbelieved the earth to be flat was liable to be subjected to the pain of death. It took the courageous Columbus, backed by his ardent "believer" and his little pioneering fleet, to lift the "zero ceiling" of understanding among his maritime contemporaries on this "disk fallacy."

Before the ink scarcely had dried on this critical letter of Mr. Froesch in which he denounces my statement "baggage and tail compartments still catch on fire or explode," the most tragic disaster in airplane history occurred in the Mt. Carmel area of Pennsylvania on June 17 from a fire which started in the baggage compartment.

Regarding "tire blowouts at landing," Mr. Froesch would find upon inquiry that the tire manufacturers subject airplane tires to repeated "sudden spin-up loads" simulating high-speed airplane landings in automatically-operated dynamometer laboratories until the rubber treads become practically worn out before tire blowouts occur. They "duplicate service failures in the laboratory and determine the general durability of the tire in regard to fatigue, impact loads, extreme shock load, and brake torque." Means are provided for attaining tire acceleration to simulate landing speeds up to a maximum of 200 miles per hour and tire loading to as high as 40,000 pounds.

Tattered tires in such worn condition before they fail from these laboratory tests would not be tolerated, of course, in the operation of scheduled airplanes by the Civil Aeronautics Authority, air-safety committees, the public, or the air lines. However, when airplane tires, which appear practically new, fail at landing, as has happened much too often and thereby invite disastrous ground loops and consequential landing gear failures with their potential injuries and deaths, it is indisputable that premature and highly accelerated deterioration of the tires has occurred.

For years until the condition was cured, the rapid deterioration and failure of practically new automobile tires was a major problem with the manufacturers, deterioration of the rubber occurring, as it did, from electrostatic ionization. The resulting ozone and nitric acid formations caused by the ionization are notoriously destructive agents of rubber products. The control of these subtle electrochemical saboteurs in destroying airplane tires is strictly an operating responsibility and not one chargeable to the tire manufacturer. The condition readily can be eliminated as explained in my article.

"Spark craters" in bearings are relatively deep-melted spots identical in appearance under microscopic examination with artificially created ones from capacitor discharges. Mr. Froesch claims such craters are caused by "overloads and high-frequency vibrations." To those who understand bearing problems, their causes, and their control, no detailed explanation is required to point out the error of his statement. The overheating of bearings, the seizure of bearings, and the disintegration of bearing surfaces, as well as the pitting of bearings, from electrostatic sparks have been treated competently in the literature and, also, have been the subject of numerous engineering meetings.

The melted holes in wing and tail surfaces of high-speed transport airplanes which I reported in my article are by no means concentrated on trailing edges. Some of them lie dangerously close to the gasoline tanks in the wings. But worst of all, explosive vapors inadvertently lurking in the enclosures of wing structures may be ignited by these prevalent electric sparks and cause damage to a wing and its control surfaces. Concerning the damage caused by such high-voltage sparking, Mr. Froesch could assure himself to advantage of this hazardous condition, before the explosion of one of his transport airplanes is required to convince him, by reading the number 12 series 1948 issue of the "Special Aircraft Accident Bulletin" published by the National Fire Protection Association.

Having conducted research, experimental, and industrial investigations for two decades or more on causes of fires and explosions from commercial solvents and liquid or gaseous fuels during industrial operations which resulted from electrostatic and other forms of ignition, I can agree with first-hand knowledge to the Funk and Wagnall definition of "explosion," as quoted by Mr. Froesch. With essentially every other statement in his letter, I disagree.

His comments, disputing the possibility of the occurrence of explosions in engine crankcases, are far removed from actual facts and from scientific knowledge recorded in the literature. I have in my files Society of Automotive Engineers' reports of engine crankcase explosions some of which even occurred in stationary Diesel engines.

Quoting from a report of the research and development department of a major oil company: "In connection with crankcase explosions, it is important to keep in mind that it is not necessary to have fully vaporized fuel or oil to support combustion, and that a mist of the right concentration in the presence of air (oxygen) can burn. In thinking of this subject, it may help you to compare crankcase explosions to explosions that occur occasionally in coal mines, where coal dust is the bad actor."

Quoting further from this same source, "Explosions may cause considerable damage to equipment and hazard to operators. It is estimated that pressures as high as 100 pounds per square inch may be developed. This is about the same result as would be obtained if a pound of dynamite were set off in a crankcase of 1,000-horsepower engine." In addition, "It is believed that crankcase explosions are caused by the burning of lubricating oil in the form of fog or droplets. If the drops are small enough, the oil burns just as readily as though it were vaporized."

For Mr. Froesch to state that the ventilation of engine crankcases purges their accumulations of explosive mixtures is definitely incorrect and wholly lacking in experimental verification. Equally incorrect is the statement that oil spray and vapors and presumed combustion products admixed with explosive fuel-air mixtures eliminate the possibility of crankcase explosions. Actually the ventilation of crankcases promotes explosion hazards. Oil spray may add fuel enrichment and, when in fog or droplet form, it adds to the already existing highly dangerous explosive conditions. Combustion products, of which water vapor, carbon dioxide, and nitrogen are the common components, must be present in relatively large volume to inhibit inflammability—a condition which is definitely not the situation in engine crankcases.

To illustrate the foregoing statement, the explosive range of carbon monoxide lies within the wide limits from 13 per cent to 74 per cent by volume, with air. By adding a volume of inert carbon dioxide equal to that of the carbon monoxide, the explosive range of the flammable fuel is only narrowed slightly from 28 per cent to 66 per cent, by volume, with air. Increasing the amount of carbon dioxide to double that of the carbon monoxide additionally narrows the explosive range from 48 per cent to 61 per cent; but, even this explosive range of 13 per cent is about double that for the many commonly used hydrocarbon fuels, such as gasoline, benzene, toluene, heptane, naptha, and many others.

Crankcase explosions in the operation of automobile and stationary engines only occur from the ignition of the flammable mixtures which is caused by mechanical sparks resulting from broken piston rings and other accidental sources or by autoignition from overheated pistons, cylinders, tearings, and allied parts. The minimum temperature required for igniting flammable mixtures of lubricating oil lies in the range of 850 degrees Fahrenheit to 900 degrees Fahrenheit, while for gasoline vapors a temperature of only 495 degrees Fahrenheit is required and for carbon monoxide 1,200 degrees Fahrenheit.

However, unlike practically all other applications of internal-combustion engines, the ever-present flammable mixtures within the crankcases of airplane engines are exposed directly to whatever electrostatic sparks occur at the bearings—in addition to the mechanical and thermal sources of ignition cited. These sparks across bearings originate as discharges to the fixed parts of the airplane from the rotating blades of the propellers which are highly electrified by virtue of their tip speeds which approach sonic value.

As to the explosion within the crankcase of the engine on the "Constellation" off the Florida coast, regarding which Mr. Froesch states "I am particularly well acquainted with the facts behind this incident," I may add that the blown-out propeller system lies buried in the Atlantic Ocean. During the war the tips of propeller blades were reported from many authentic sources, including propeller manufacturers, to have been broken or shot off, not uncommonly, without causing consequential damage to the propeller system or to the engine. Airplanes thus damaged were reported to have not only completed their missions but, also on occasions, to have taken to the air again without repairs.

Mr. Froesch, in questioning the reliability of reporters of the press and radio, does little credit to the intelligence of these men. It is fair to state that their information comes, as a rule, from those who do know the facts. Also it is justified in saying that these facts frequently are suppressed or contradicted, subsequent to publication, for politic or other reasons.

As an authority in investigating the remains of many major explosions, my general observation is that it is most hazardous to permit sparks within an enclosure which is pervaded with an inflammable fuel-air mixture. Unofficial air line reports to me substantiate the fact that certain materials and operating conditions found in air transports have indicated the prevalence of electrostatic sparking in wing structures, in cabins, and in baggage compartments. There is no reason to doubt that some of these conditions might lead or have lead to aviation disasters.

Civil authority makes little allowance for ignorance of man-made laws. Nature grimly makes none for her laws. Electrostatic fire and explosion hazards in the many phases of aviation flight and ground operations are as real as life or death and definitely not theoretical or speculative, as Mr. Froesch would have one believe. As common carriers, the air lines and the airplane manufacturers as well should employ engineers who are specialized in this vital field of electrostatics. These engineers should be experienced in the sources and hazards of electrostatic ignition and in the parasitic origins of explosive fuel-air mixtures.

Congressional air safety committees and air policy boards are demanding improvement in the design, operation, and maintenance of airplane equipment and airline operating procedures. May the day be speeded when an understanding recognition is conceded to the prevalence of electrostatic fire and explosion hazards on airplanes so that the simple and inexpensive corrective measures necessary for the elimination of the gruesome toll of accidents, holocausts, and deaths from these causes finally may be instituted.

ROBIN BEACH (F' 35)

(Robin Beach Engineers Associated, Brooklyn, N. Y.)

American Engineering Association

To the Editor:

The article by AIEE Past-President B. D. Hull advocating the founding of an American Engineering Association (*EE, Apr '48, pp 313–17*) should find active support from every engineer who is interested in the standing of the professional engineer. There is no doubt of the urgent need for an engineering organization, which, by virtue of a recognized professional standing indirectly would be influential socially, and to a moderate extent politically.

The familiar adage, "United we stand, divided we fall," is just as applicable today as ever before, and in contemplating the ineffectual efforts of the many individual engineering societies towards obtaining a higher degree of professional recognition from the general public, the thought comes to mind as to the reason why the engineering profession with so many years of organized professional practice has failed so signally in carrying out the responsibilities toward the individual member with respect to professional standing.

As Mr. Hull pointed out in his article, the engineer, although he can come to an agreement on purely technical questions, does not co-operate on questions and aims pertaining to the economic and social aspect of every day living in regard to contacts with other professions and the lay public. Intelligent, individual thought is a valuable asset in a true democracy, and should be translated into positive action by means such as a majority referendum vote, or representation by elected members who are delegated to present the views of a majority.

Under our present system of existing separate engineering societies, there is little possibility of presenting the majority viewpoint of the mass of engineers, as each society has its own individual program which mainly stresses the purely technical part of engineering activity. Taking for example the medical profession, a physician or surgeon is a member of the American Medical Association, the national medical society which does represent, and speak for any or all members of the medical profession, irrespective of whether the individual member is practicing a specialized part of medical practice. Similarly a lawyer also is identified as such whether he be a corporation lawyer, a criminal lawyer, or any other type of lawyer.

Does not this possibly explain why the legal and medical professions which have a single national society for representation possess a higher professional standing than does the engineering profession?

In my opinion, to rectify this condition a far more drastic application than even Mr. Hull recommends is necessary. I do not concur with Mr. Hull's suggestion that a proposed American Engineering Society could function properly together with the other engineering societies with their present identity and authority.

Why persist in half measures, which in the past have been tried several times and found to be inadequate and unsuccessful?

I would recommend that the American Engineering Society be organized so as to absorb all existing engineering societies which are national in scope. The existing individual society local sections easily could fit into the local chapters of the new society, and be carried on as purely technical sections. It easily can be understood that the various engineering societies are reluctant to relinquish their identities and responsibilities, however, I believe that a thorough presentation of the facts and issues to the members of all the engineering societies would find a response to the idea that amalgamation and centralization of publicity functions is necessary for the general welfare of all engineers.

To the general public an engineer even though he is a specialist in one of the various branches of engineering, is titled as "engineer" and as it is from the general public that we must receive a large part of our professional recognition it would seem to be good policy to present our ideas, services, and social and political opinions, to the public as "engineers" rather than by a specialized subtitle which in the public mind may have a tendency to associate the engineer with the specialized trades.

The issue as it stands at present is clear and in my opinion can be explained by one question, "Have the engineering societies, as now constituted, successfully met the need for improvement in the professional status of the engineer?" If they have met this challenge there is no need for an additional engineering society. However, according to Mr. Hull and many other authorities, the engineering societies definitely have failed in this respect, this failure being reflected in the large number of engineers of standing who are not members of a national engineering society. We also should face the fact honestly that thousands of society members are such in name only, regularly paying dues and taking a rather remote interest in the various technical activities conducted by the specialized sections.

As engineers are human beings with the same diversity of aspirations, hobbies, and recreational pursuits as any other person, whether a businessman, mechanic, clerk, or laborer, does it not seem reasonable to expect a more diversified program of activity.

It is certainly true that it is to the technical activities of the engineering societies that we owe whatever professional standing we possess, but considering that this recognition springs only from scientific circles, can we not consider that our professional recognition thus is restricted and limited by this fact. No scientific product can be presented successfully to the general public without considerable advertising and salesmanship, which has as an objective the translation of scientific attainment and advantages to the lay public in simple terms.

If we desire the general public to recognize and honor the contribution of the engineering profession toward publicizing the conveniences and comforts of modern civilization, we must recognize the necessity of adequate publicity. How this should be accomplished is a matter for consultation, and considerable care should be taken that a long range publicity program be formulated carefully.

Correlated social activities also will require some planning to be of any value. However, whatever program is planned and undertaken, it is my opinion that all engineers should have the opportunity of taking part. An American Engineering Society with the large membership, prestige, and representation it would possess certainly should be able to acquaint the public at large materially as to the engineer's status in public life.

It is human nature to measure ability, professional standing, and social status to a great extent on the individual's self-valuation, granted that such valuation is not egotistical or exaggerated, and which is reflected in the individual's self-expression in conduct, dress, conversation, and so forth. Collectively this valuation is totally dependent on the written word, and by addresses to the general public by the leaders in the profession.

The responsibility of representing the engineering profession in so far as contacts with the public are concerned should not, in my opinion, be vested in any single individual or any group of individuals who do not possess a common or co-ordinated policy. An American Engineering Association possessing a membership containing the recognized leaders in all branches of engineering would be in a position to progress a sound constructive program which, being national in scope and embracing all engineers ultimately would be of benefit to every engineer, and possibly prove to be an incentive to those engineers of standing, who, at present are not interested in engineering society membership.

VERNON UTTLEY

(Chief, Projects Branch, United States Army Forces Antilles, Office of the Antilles Engineer, c/o Postmaster, Miami, Fla.)

To the Editor:

In recent discussions as to the need for some over-all engineering society to represent the profession in general the suggestion has been made repeatedly that such an organization already exists—the National Society of Professional Engineers.

Actually, the National Society of Professional Engineers is very poorly representative of the engineering profession. Its membership is limited to registered engineers. Figures in the recent report, "The Engineering Profession in Transition," indicate that civil, electrical, and mechanical engineers make up about 70 per cent of all engineers, about equally divided between the three groups. But by far the majority of registered engineers are civil engineers, with relatively few electrical or mechanical engineers registered.

In the two states in which I am registered at present, Arizona and Michigan, civil engineers make up the bulk of the registration.

The last census shows better than a quarter of a million engineers of one kind or another. Under the present registration laws there is no need for the majority of these to be registered. The reason registered engineers are predominately civil is because it is mainly the civil engineers who are affected by the registration requirements. It is unlikely that there will be any serious change in the registration requirements for some time to come.

To summarize, then, the National Society of Professional Engineers represents, after a fashion, registered engineers. But registered engineers are very poorly representative of engineers in general. As an organization to represent the engineering profession in general properly this society hardly qualifies.

(You know, I resent the attitude of the National Society of Professional Engineers that one is not an engineer unless registered. Under the present laws this simply is not so.)

HAROLD NEVIN CAREY

(Associate member, American Society of Civil Engineers, Member American Association of Engineers, 1806 North 11th Street, Phoenix, Ariz.)

To the Editor:

Mr. Hull's article in the April issue on an American Engineering Association was very comprehensive and timely. There seems to be general agreement that an over-all organization to direct the professional, economic, and social program of the engineering profession is needed urgently. It also is agreed generally that the existing engineering societies should continue to carry on their technical activities as at present. If the existing professional societies, such as the American Association of Engineers or the National Society of Professional Engineers, were to continue as they are it would result in duplication of professional activities with the new association. Obviously such duplication is to be avoided and a plan to accomplish this should be worked out which will be as satisfactory to all existing societies as is possible. It appears that there are three alternatives as follows:

1. Professional engineering societies continue on an antonomous basis providing individual membership without any connection with technical societies.

2. Engineering societies co-operate to form a new over-all society which includes representation of existing technical societies as well as individual membership but which probably would not include existing professional societies.

3. Technical societies co-operate with professional societies to change the latter from an antonomous body to a joint organization to represent technical societies as well as individuals.

I think all will agree that plan 1, which would force engineers to join an outside antonomous society having no connection with their technical society in order to secure representation in professional matters, is not the answer. I believe we also can agree that plan 2 of the technical societies forming some interlocking over-all organization without regard to the existing professional societies is also not the answer. I am sure we all can agree that if under plan 3 the existing professional societies can be consolidated and changed so as to be interlocked with and represent the existing technical societies as well as their individual members of certain qualified grades, it would provide the best solution.

It would seem to be to the best interests of the engineering profession if the National Society of Professional Engineers would come forth with a concrete plan to convert their society into a national society such as Mr. Hull visualizes.

ROY E. KISTLER (F '46)

(Pacific Telephone and Telegraph Company, Seattle, Wash.)

Electrical Essay

To the Editor:

In answer to your electrical essay in the July 1948 issue of *ELECTRICAL ENGINEERING* (*EE, Jul '48, pp 653–4*), an induction motor is capable of delivering power at a leading power factor to the line when operating at above synchronous speed. This principle finds application in the process of regenerative braking on electrified railroads.

The rotor current, $I_2 = \frac{e_2 s}{r_2 + jx_2 s}$ (assuming 1 : 1 ratio of transformation), where E_2, r_2, x_2 are the rotor induced voltage, rotor resistance, and rotor reactance, respectively. Rationalizing this expression,

$$I_2 = E_2\left(\frac{r_2 s}{r_2^2 \times x_2^2 s^2} - j\,\frac{r_2 s^2}{r_2^2 \times r_2^2 s^2}\right)$$

As shown in the essay, the rotor voltage will be $-E_2$ when s is negative. By substituting $-E_2$ for E_2 and $-s$ for s in the foregoing equation, it can be seen that the rotor current I_2 will lead the rotor voltage by an angle determined by r_2, x_2, and s.

However, to say without qualification that an induction motor will run as an alternator (that is, deliver power to the line) appears to be a violation of the law of conservation of energy. As the line itself presumably does not deliver power to the machine, what supplies the excitation?

To illustrate, assume an induction motor is used to drive a d-c shunt or compound machine acting as a generator in parallel with a second similar machine driven by a prime mover. Assuming that the second machine were to speed up, it evidently would drive as a motor, the machine connected to the induction motor. Since to do this would mean that the induction motor would be rotated at greater than synchronous speed, it appears that the induction motor is acting as a generator. Yet as asked in the foregoing, where is the necessary field excitation coming from?

From Lenz's law, we know that the voltage of the stator (the line voltage) will induce a voltage in the rotor (E_2 or $-E_2$ as the case may be) which in turn will induce a counter voltage in the stator. This counter voltage is proportional to $1-s$ and tends to limit the flow of current to the stator. Assuming no losses, at no load the induction machine would run at synchronous speed approximately and at this point it can be seen that counter voltage would approach the line voltage and the stator current would approach zero. As s is made negative, the counter voltage will exceed the voltage of the line, presumably causing power to flow from the stator to the line as the phase relationship of the rotor voltage E_2 has been reversed, causing, as a consequence of Lenz's law, a corresponding reversal in the phase of the stator voltage. As shown in the essay the relative phases of the rotor and stator currents are not reversed. Thus, multiplying the stator voltage and current together will show that the volt-amperes of the machine have been reversed. Doing this multiplication vectorially will show immediately that the power is reversed above synchronous speed and that the machine is operating at a leading power factor. Although this explains the answer to the essay it does not satisfactorily explain to me how it is possible for the induction machine to change over from a motor to a generator. The fact that the voltage induced by the stator is now higher than that of the line seems to nullify the possibility that the line itself is providing the necessary excitation. As there is apparently no external source of power I only can conclude that the excitation is provided by mutual induction between the rotor and stator. Accordingly, it is my guess that an equilibrium condition is reached when the voltage induced in the stator approaches as a limit the line voltage and, consequently, there is no flow of power in either direction, except that making up the losses.

Where is the fallacy of this argument?

WILLIAM E. WARDEN

(Student, Pratt Institute, Brooklyn, N. Y.)

Transactions Correction

To the Editor:

As AIEE technical paper 47-266 entitled "Diffusion of Electric Current into Rods, Tubes, and Flat Surfaces," which was presented at the Midwest general meeting in Chicago on November 7, 1947, or has been published in AIEE *TRANSACTIONS*, vol. 66, 1947, pages 1496–1502, perhaps you can print this letter in *ELECTRICAL ENGINEERING* correcting an error and also introducing an algebraic simplification, both kindly called to my attention by A. C. Sim of the electronics engineering department of the British Thomson-Houston Co., Ltd. in England.

In defining the dimensionless ratios of equation 9 in the paper, one has the choice of referring dimensions to either the inner radius a or outer radius b of the tubular conductor. The latter is, however, most convenient since it is applicable to the limiting case of a solid rod when $a=o$. However, in the initial derivations, both ratios were used and inadvertently equations 19, 20, and 21 were recorded in the paper inconsistent with defining equations 9. In presenting here the corrected equations it is also desirable to present them in simplified form by using the identity suggested by Mr. Sim, namely:

$$\frac{Z_{01}(x)}{Z_{01}(\alpha x)}=\alpha\frac{N_1(\alpha x)}{N_1(x)}$$

where α is any fixed constant. The corrected and simplified equations 19, 20, and 21 then become

$$K=1+\sum_{n=1}^{n=\infty}\left[\frac{k^2-1}{k^2\left\{1-\left(\frac{N_1(\bar{\mu}_n)}{N_1(\bar{\mu}_n/k)}\right)^2\right\}}\right]\epsilon^{-2\bar{\mu}_n^2 t} \tag{19}$$

$$K_{av}=1-\sum_{n=1}^{n=\infty}\left[\frac{k^2-1}{k^2\left\{1-\left(\frac{N_1(\bar{\mu}_n)}{N_1(\bar{\mu}_n/k)}\right)^2\right\}}\right]\times\left[\frac{1-\epsilon^{-2\bar{\mu}_n^2 t}}{2\bar{\mu}_n^2 t}\right] \tag{20}$$

where roots $\bar{\mu}_n$ are to be determined from

$$J_1\left(\frac{\bar{\mu}_n}{k}\right)N_1(\bar{\mu}_n)-J_1(\bar{\mu}_n)N_1\left(\frac{\bar{\mu}_n}{k}\right)=0 \tag{21}$$

It should be noted that equations 19, 20, and 21 as originally given, although all inconsistent with defining equations 9, are nevertheless mutually consistent so that the numerical results plotted in Figure 6 of the paper are correct as shown.

K. W. MILLER

(Assistant director of research, Armour Research Foundation, Chicago, Ill.)

New Watt-hour Meter

To the Editor:

I. E. Kinnard's article "A New Watt-hour Meter" (*EE, Jul '48, pp 627–9*) was undoubtedly of great interest to all electrical men concerned with measurement. The article gives the reader the impression that the author regards the magnetic suspension as the most important of the several new features incorporated in this meter. In view of this, therefore, there is a serious omission in the article and one that *ELECTRICAL ENGINEERING* hardly can overlook.

I am referring to the complete absence of any reference to the work of Stanley and the meter he manufactured which incorporated a magnetic suspension of the moving element.

Mr. Kinnard, in his introduction, mentions Edison, Thomson, and Shallenberger. Why did he omit any reference to Stanley when the Stanley meter was the pioneer in magnetically suspended rotor constructions?

It is quite true that the Stanley magnetic suspension is well known to the older meter engineers but omission of a reference to this meter with the resulting implication that magnetic suspension is a brainchild of Mr. Kinnard and his associates is unfair to the general reader.

G. G. WAITE (A' 29)

(Chief engineer, Sangamo Company Limited, Leaside, Ontario, Canada)

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Basic Radio Propagation Predictions for October 1948, three months in advance, CRPL Series D. Number 47. A National Bureau of Standards publication. Superintendent of Documents, Government Printing Office, Washington 25, D. C., 10 cents.

Kabelitems Number 27. "Color Notation describes the methods of color notation that have been applied to Vinylite plastic electrical extrusion compounds. Both the Muntell and the T.C.C.A. color systems are described in their application to achieve National Electrical Manufacturers Association and United States Navy Bureau of Ships standards for insulation. Bakelite Corporation, Advertising Department, 300 Madison Avenue, New York 17, N. Y.

Edison Electric Institute–National Electrical Manufacturers Association Recommended Standards for Distribution Transformers. NEMA publication No. 114. This fourth report of the Joint Committee of the EEI and NEMA on Standards for Distribution Transformers contains design standards for certain mechanical and electrical features of overhead-type single- and 3-phase distribution transformers rated 500 kva and smaller, high voltage 2,400–15,000 volts, low voltage 600 volts and below. It supersedes both the second and third reports for distribution transformers. 16 pages. 80 cents.

Sales Data Sheet. Testing of welds in plate, thin sheet, and other sections with the Sperry Supersonic Reflectoscope, using a new angle transmitter, is described fully in Sales Data Sheet 3021, a publication of Sperry Products, Inc., 1505 Willow Avenue, Hoboken, N. J.

Bibliography on Engineering Office Filing. "Filing Systems for Engineering Offices," list of 41 references to books and articles on systems for the filing of notes, correspondence, abstracts, reprints, drawings, maps, catalogues. The first of a series of bibliographies to be issued by the Engineering Societies Library, the booklet may be purchased from the Engineering Societies Library, 29 West 39th Street, New York 18, N. Y. Price $2.

Principal Electric Utility Generating Stations and Transmission Lines in the United States. Comprising 11 regional maps and six supplementary sheets, the series shows, in general, transmission lines of 22 kv and above, electrical utility generating stations of 1,000 kw and above, and industrial electric generating stations of 1,000 kw and above when interconnected with an electrical utility. The maps are sold exclusively by the Federal Power Commission, Washington, D. C. The complete set of 11 with supplementary sheets is $2.50. Individual maps are 25 cents each. The order number for the set is FPC-M-8.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

FORMING OF AUSTENITIC CHROMIUM-NICKEL STAINLESS STEELS. Assembled and edited by V. N. Krivobok and G. Sachs. International Nickel Company, 67 Wall Street, New York, N. Y., 1948. 309 pages, illustrations, diagrams, charts, tables, $11^1/_4$ by $8^1/_2$ inches, cloth, $4. This book gives fabricators of metal equipment a better understanding of the adaptability of stainless steels to all modern processes of forming. It presents a detailed description of the modern forming procedures as applied to chromium-nickel stainless steels and as practiced in United States plants. Bending and straight flanging, forming of curved sections and tubing, deep drawing, die forming, forming of contour flanged parts, and forming by miscellaneous methods are discussed. The specific examples of forming technique are supplemented by details of tool design and tool materials, lubricants, data on dimensions, and consecutive steps on fabrication.

ACHIEVEMENTS IN OPTICS. (Monographs on the Progress of Research in Holland.) By A. Bouwers. Elsevier Publishing Company, New York, N. Y., and Amsterdam, Holland, 1946. 135 pages, illustrations, diagrams, charts, tables, $8^1/_4$ by $5^3/_4$ inches, paper, $2.50. Divided into four sections, this monograph deals with research during the war years. Part 1 considers the new optical systems involved in the concave spherical mirror, the Schmidt-Camera, and the concentric mirror system. In part 2, a new microscope, telescopes, and cameras are treated. The work on geometrical optics is considered in part 3, while part 4 covers phase contrast and the diffraction theory of aberrations.

AUTOMATIC REGULATION, Volume I. By W. R. Ahrendt and J. F. Taplin; preliminary edition, published and distributed by Ahrendt and Taplin, Post Office Box 4673, Washington 20. D. C., 1947. 171

pages plus Appendixes A-D, illustrations, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{3}/_{4}$ inches, cloth, \$3.50. Following a brief introductory chapter, the mathematical background is established. Differential equations and the Laplace transformation are discussed in their application to properties of closed causal loops. There is an adaptation of the methods of Fourier through frequency spectrum analysis, and the analysis of multi-loop systems is undertaken. A bibliography, problems, and a glossary complete the book.

DIRECT-CURRENT MACHINERY. By G. C. Blalock. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 367 pages, illustrations, diagrams, charts, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, \$3.75. Intended for relatively brief courses, this text presents a concise picture of basic and specialized machines and their controls. Applications of theory are given in practical examples, problems and illustrations. Fundamental derivations are supplied for most of the equations. Operating characteristics of generators and motors are presented, and a chapter on batteries is included.

ELECTRETS. By T. A. Dickinson. Plastics Research Company, Box 346, Alhambra, Calif., 1948. 32 pages, diagrams, charts, tables, $5^{1}/_{2}$ by 4 inches, fabrikoid, \$2.50. Written for engineers and technicians, this little book is devoted to methods of rearranging atoms in nonmetallic materials so as to produce electrical equivalents of permanent magnets. History and theory are presented as well as potential applications. There is a bibliography of periodical articles on the subject, and pertinent books and magazines are listed.

ELECTRICAL SOIL STERILIZATION BY IMMERSION HEATERS. Technical Report, Reference W/T14. By C. A. Cameron Brown and P. Wakeford. British Electrical and Allied Industries Research Association, 15 Savoy Street, London, W. C. 2, England, 1947. 17 pages, illustrations, diagrams, charts, tables, 11 by $8^{1}/_{2}$ inches, paper, 6s.6d. This report describes an experimental investigation into the conditions governing the sterilization of soil for horticultural purposes by insulated heating tubes. Working details are given of actual sterilizers made up and worked successfully for several seasons.

ELECTRONIC ENGINEERING MASTER INDEX 1946. Edited by F. A. Petraglia. Electronics Research Publishing Company, 2 West 46th Street, New York, N. Y., 1947. 202 pages, 10 by $6^{3}/_{4}$ inches, fabrikoid, \$14.50. About two-thirds of the 7,500 new entries included in this supplement relate to the technical literature of the period from July 1945 to December 1946. The remaining third consists of miscellaneous entries, principally from foreign periodicals, ranging over the last decade. Two new sections are the "Bibliography of Engineering Texts" and a survey of recent manufacturers' literature. The cumulative cross-index at the end of the book serves as a guide to both the present compilation and the 1925–1945 edition.

ELECTRIC POWER TRANSMISSION. By M. P. Weinbach. Macmillan Company, New York, N. Y., 1948. 364 pages, diagrams, charts, tables, $9^{1}/_{2}$ by 6 inches, cloth, \$5.50. Emphasizing the electrical problems of power transmission, this book provides a knowledge of the physical phenomena involved and the mathematical processes needed for their solution. The 3-phase system, circuit properties of transmission lines, voltage control, steady state power limits, and other problems are considered.

FREQUENCY MODULATION ENGINEERING. By C. E. Tibbs, foreword by L. H. Bedford. Chapman and Hall, Ltd., London, England, 1947. 310 pages, illustrations, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, 28s. Presenting basic theory, the early chapters deal with the frequency modulation of carrier waves and with interference suppression. Succeeding chapters consider propagation, aerials, transmitters and measurements. The remainder of the book is devoted to a description of the technique and circuits employed for frequency modulation and reception.

FUNDAMENTAL ELECTRONICS AND VACUUM TUBES. By A. L. Albert. Revised edition, Macmillan Company, New York, N. Y., 1947. 510 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by 6 inches, cloth, \$6. Designed for use in college and university courses, this book contains the fundamental principles of electronics and related phenomena. In this revised edition the author has added review questions and new problems. Selected references follow each chapter.

GEMS AND GEM MATERIALS. By E. H. Kraus and C. B. Slawson. Fifth edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 332 pages, illustrations, diagrams, charts, tables, 9 by $5^{1}/_{2}$ inches, cloth, \$4. This book presents authoritative information about minerals and materials used or gem and ornamental purposes. The considerable revision relates to crystal forms, physical and optical properties, gem polishing and cutting, and manufactured gems. A new section is included on the determination of crystal structure by X-ray methods. The technical data are presented in tabular form for classification purposes.

HANDBOOK OF INDUSTRIAL ELECTROPLATING. By E. A. Ollard and E. B. Smith; published by "Metal Industry" (Louis Cassier Company, Ltd.), distributed by Iliffe and Sons, Ltd., London, Birmingham, Coventry, and Manchester, England, and Glasgow, Scotland, 1947. 308 pages, illustrations, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, linen, 15s. Omitting theory, this book provides full practical information for all those whose duty it is to design, erect, maintain, or operate electrodeposition plants, and for the laboratory worker who must deal with plating solutions. The book is divided into eight sections: electric equipment; deposition plant; solution formulas; special formulas; solution testing; deposit testing; glossary; miscellaneous information and tables.

HEATING AND VENTILATING BUYERS' DIRECTORY, 1948 edition. Edited by C. Strock. Industrial Press, 148 Lafayette Street, New York, N. Y.; 228 North La Salle Street, Chicago, Ill. 320 pages, illustration, 8 by $5^{1}/_{2}$ inches, paper, \$1. This book covers the fields of air conditioning, piping, heating, refrigeration, ventilation, and air sanitation. It is primarily a classified product directory, listing the sources of equipment, supplies, and services.

HEATING AND VENTILATING'S ENGINEERING DATA BOOK. By C. Strock. Industrial Press, 148 Lafayette Street, New York, N. Y., 1948. Paged in sections, diagrams, charts, maps, tables, $11^{1}/_{4}$ by $8^{1}/_{2}$ inches, fabrikoid, \$7. Purely practical in character, this reference work emphasizes the data needed in actual design with only sufficient text to explain the use of the data. Information is included on the heat pump, electrothermal storage, snow melting, heating with Diesel engines, solar water heating, and radiant heating. One section is devoted to the law of contracts and other legal subjects which concern heating men.

(The) INDUSTRIAL ENVIRONMENT AND ITS CONTROL. By J. M. Dalla Valle. Pitman Publishing Corporation, New York, N. Y., and London, England, 1948. 225 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$4.50. This book deals with engineering methods for the control of health hazards in factories, including air sanitation and exhaust ventilation, illumination, noise, and thermal environment. References follow each chapter. No prerequisites other than preliminary engineering and some knowledge of industrial hygiene are required.

LORAN LONG RANGE NAVIGATION. Edited by J. A. Pierce, A. A. McKenzie, and R. H. Woodward. McGraw-Hill Book Company, New York, N. Y., 1948. 476 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$6. This book gives a complete account of the design and use of the long-range pulse navigation system known as loran, both in its original form and as sky-wave synchronized loran. Sections are included on radio propagation at loran frequencies and on methods for the computation and preparation of loran navigational charts.

MANUAL OF MATHEMATICS AND MECHANICS. By G. R. Clements and L. T. Wilson. Second edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 349 pages, diagrams, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$3.25. This manual contains facts and formulas that are useful in college and engineering schools. In this revised edition the tables of differentials and integrals have been expanded, and the author has included formulas for the solution of spherical triangles by Ageton's method, also new material on the applications of mathematics to certain topics in electrical engineering.

NEW DEVELOPMENTS IN FERROMAGNETIC MATERIALS. (Monographs on the progress of research in Holland.) By J. L. Snoek. Elsevier Publishing Company, Inc., New York, N. Y., and Amsterdam, Holland, 1947. 136 pages, illustrations, diagrams, charts, tables, $8^{1}/_{4}$ by $5^{3}/_{4}$ inches, paper, \$2.50. Covering research done during the war period, this report discusses the statics and dynamics of ferromagnetism and the development of magnetic materials. Emphasis is placed on the magnetic after-effect, disaccomodations, and the elastic after-effect.

PARAMAGNETIC RELAXATION. By C. J. Gorter. Elsevier Publishing Company, New York, N. Y., London, England, Amsterdam, Holland, Brussels, Belgium, 1947. 127 pages, diagrams, charts, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, \$2.25. This small volume presents a general survey of the subject based largely on Dutch research. The introductory material covers normal paramagnetism, fields and ion interaction, paramagnetic dispersion, and absorption. Experimental methods and results are given.

PRINCIPLES OF QUANTUM MECHANICS. By P. A. M. Dirac. Third edition. Clarendon Press, Oxford, England; Oxford University Press, New York, N. Y., 1947. 311 pages, tables, $9^{1}/_{2}$ by 6 inches, cloth, \$9. Rewritten to include the results of research since 1935, the main alteration is the introduction of the notation of bra and ket vectors. The presentation of the theory of systems with similar particles is now based on Fock's treatment of the theory of radiation. A further development of quantum electrodynamics, including the theory of the Wentzel field, has been included.

POWER SYSTEM STABILITY. Volume I, Elements of Stability Calculations. By E. W. Kimbark. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1948. 355 pages, illustrations, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{4}$ inches, cloth, \$6. This first volume of a projected 3-volume work covers the elements of the stability problem, the principal factors affecting stability, the simplified methods of making stability calculations, and the practical application of these methods to actual power systems.

RADAR BEACONS (Massachusetts Institute of Technology Radiation Laboratory Series Number 3). Edited by A. Roberts. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 489 pages, illustrations, diagrams, charts, maps, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$6. Dealing with the design and use of radar responder beacons, this volume gives comprehensive and complete information on their field installation, operation, and maintenance. The employment of systems involving beacons for navigation is critically discussed, and systems using radar sets as interrogators as well as systems using special interrogators both are treated.

RADIO AMATEUR'S HANDBOOK, Standard Manual of Amateur Radio Communication. 25th edition, 1948. Published by American Radio Relay League, West Hartford, Conn. 608 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by $6^{1}/_{2}$ inches, paper, \$2; \$2.50 foreign. This annual publication covering the theory, principles, and design of short-wave radio has been revised as usual and rearranged for more effective use. New chapters have been added on ultrahigh frequency, microwaves, interference, emergency operation, and assembling a station. Material is included on general workshop operations and detailed instructions for the building of various types of equipment.

RESEARCH IN INDUSTRY, ITS ORGANIZATION AND MANAGEMENT. By C. C. Furnas, editor, prepared by and published for Industrial Research Institute, Inc. D. Van Nostrand Company, Toronto, Ontario, Canada, New York, N. Y., London, England, 1948. 574 pages, illustrations, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$6.50. Thirty-two research executives provide authoritative discussions of the various aspects of industrial research. Intended as a practical guide for the organization and functioning of a research department, the book deals with general matters such as the formulation of policies as well as with specific topics such as the research budget, reports, patents, personnel, and the effective correlation of research with production.

(A) SURVEY OF THE PRINCIPLES AND PRACTICE OF WAVE GUIDES. By L. G. H. Huxley. University Press, Cambridge, England; The Macmillan Company, New York, N. Y., 1947. 328 pages, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, \$4.75, (21s. in England). This book is an introductory summary of the recent developments in the application of wave guides. It considers general background material, progressive electromagnetic waves in wave guides, formulas for field components, wave guide impedances and techniques, and cavity resonators.

TABLES OF THE BESSEL FUNCTIONS OF THE FIRST KIND OF ORDERS TEN, ELEVEN, AND TWELVE. (Harvard University, Annals of the Computation Laboratory, volume 7.) TABLES OF THE BESSEL FUNCTIONS OF THE FIRST KIND OF ORDERS THIRTEEN, FOURTEEN, AND FIFTEEN. (Harvard University, Annals of the Computation Laboratory, volume 8.) TABLES OF THE BESSEL FUNCTIONS OF THE FIRST KIND OF ORDERS SIXTEEN THROUGH TWENTY-SEVEN. (Harvard University, Annals of the Computation Laboratory, volume 9.) Harvard University Press, Cambridge 38, Mass., 1947–1948. Volume 7, no pagination; volume 8, no pagination; volume 9, 764 pages, tables, $10^{3}/_{4}$ by 8 inches, cloth, \$10 each. In these three volumes are continued the tables computed by the automatic sequence controlled calculator. The tabulation is carried to ten decimal places, with a wide range of argument and order, fine argument interval and a high degree of accuracy. Volume 3 of the series describes the methods of computation and interpolation.

ALTERNATING-CURRENT MACHINERY. By J. G. Tarboux. International Textbook Company Scranton, Pa., 1947. 652 pages, illustrations, diagrams charts, tables, $9^1/_4$ by 6 inches, fabrikoid, \$6. Written from the basic-circuit point of view, this volume first presents the fundamental laws of the generalized circuit and circle diagram, and then shows how each individual machine is a special case. An appendix contains a variety of illustrative experiments.

INSTRUMENTATION AND CONTROL IN THE GERMAN CHEMICAL INDUSTRY. *PB 75861.* By C. H. Gregory, H. B. Appleton, A. P. Lowes, and F. C. Whalen. Mapleton House, 5415 Seventeenth Avenue, Brooklyn 4, N. Y., 1947. 157 pages, illustrations, diagrams, charts, tables, 8 by $5^1/_4$ inches, paper, \$6. Derived from an investigation by the British Intelligence Objectives Subcommittee, this volume reports the application of industrial instruments in the German chemical industry. The designs and manufacture of standard and special instruments are described, including recent research and development. Instruments used to measure flow, pressure, temperature, and density are discussed, as well as instruments used for analysis, measurement, and automatic control.

(The) JACOB INTEGRAPH INSTRUCTIONS AND TYPICAL PROBLEMS. By B. C. Jacob, 205 North Mountain Street, Bay City, Mich.; photo offset by Polygraphic Company of America, New York, N. Y., 1947. 126 pages, diagrams, charts, tables, $8^1/_4$ by 6 inches, paper, apply to author. The Jacob Integraph is a small transparent triangle having ruled lines and small perforated holes so placed as to make it possible to perform graphically a variety of arithmetical and analytical computations. It may be used with an ordinary tee-square or triangle or as an attachment on a universal drafting machine. The accompanying instruction book gives a detailed explanation of the simple fundamental operations, and of more complex problems in mechanics and engineering.

MATHEMATICAL THEORY OF ROCKET FLIGHT. By J. B. Rosser, R. R. Newton, and G. L. Gross. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 276 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$4.50. Originally prepared as a report to the Office of Scientific Research and Development on wartime laboratory research, this volume now has been issued with the addition of a considerable amount of expository material. A simple explanation precedes the mathematical part of each section to provide a general idea of rocket flight which makes the book is useful both as a handbook for the trained scientist with no previous experience in the field and a text for the reader with little scientific training.

MEASUREMENT OF COLOUR. By W. D. Wright. Adam Hilger Ltd., London, N.W. 1, England 1944. 223 pages, illustrations, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, 30s. (obtainable from Jarrell-Ash Company, 165 Newbury Street, Boston, Mass., \$9.75 plus postage). Giving a comprehensive but concise account of the principles and methods of color measurement and specification, this volume also describes visual and photoelectric instruments, as well as the relation of color physics to many technical processes. The principles, methods, and applications of the fundamental trichromatic system of color measurement are described.

MECHANICS. By J. C. Slater and N. H. Frank. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 297 pages, diagrams, tables, $9^1/_4$ by 6 inches, cloth, \$4. The first of several volumes intended to replace the author's "Introduction to Theoretical Physics," this book emphasizes the topics important to mechanics, and those which make the study of mechanics the fundamental basis of all theoretical physics. Modern mathematical methods, such as ordinary and partial differential equations, vector analysis, and so forth are used. Appendixes contain the mathematical background for these methods for the use of those familiar with calculus and differential equations.

MEN AND VOLTS AT WAR, THE STORY OF GENERAL ELECTRIC IN WORLD WAR II. By J. A. Miller. McGraw-Hill Book Company, Whittlesey House Division, New York, N. Y., and London, England, 1947. 272 pages, illustrations, tables, $9^1/_4$ by 6 inches, cloth, \$3.75. This is the story of the General Electric Company's accomplishments in World War II. The first part deals with the company's activities in the making of combat equipment, while products for industry are considered in part two. General Electric's role in the Manhattan District project is treated.

FUNDAMENTAL PRINCIPLES AND APPLICATIONS OF INDUCTION HEATING. By "Heat-Treater." Chapman and Hall, Ltd., 37 Essex Street, London, W.C. 2, England, 1947. 147 pages, illustrations, diagrams, charts, tables, 9 by $5^1/_4$ inches, cloth, 10s.6d. The development and applications of industrial heating are discussed, as well as the principles of induction and coil design and the choice of frequency equipment. Applications to surface hardening, internal hardening, tempering, forging and other processes are considered.

FUNDAMENTALS OF ENGINEERING MECHANICS. By A. Sloane. Prentice-Hall, Inc., New York, N. Y., 1947. 379 pages, diagrams, tables, $9^1/_4$ by 6 inches, cloth, \$5.65. This volume deals with the usual material on statics and dynamics which is treated in a text on engineering mechanics. In addition, the principle of virtual work, Mohr's circle as applied to moments of inertia and products of inertia, and a brief introduction to the subject of mechanical vibrations have been included.

GAS TURBINE CONSTRUCTION, INCLUDING OPERATION AND MAINTENANCE. By R. T. Sawyer. Prentice-Hall, New York, N. Y., 1947. 411 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$7. In addition to construction data, this volume also covers operating details and maintenance. Part 1 deals with the gas turbine as heavy equipment for stationary, marine, or locomotive service; part 2 covers turbochargers; and part 3 describes the various types of aircraft gas turbine equipment.

INDUSTRIAL APPLICATIONS OF INFRARED. by J. D. Hall. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 201 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$4. Written from a practical point of view, this up-to-date manual shows the executive, supervisor, plant engineer, and so forth, how to use infrared radiation to achieve better and more economical surface finishes and how to apply it to other industrial heating jobs. The book describes what equipment is available, discusses its operating characteristics, and provides the essential design and installation data needed to adapt infrared to the specific requirements of various production processes.

ELECTRIC DISTRIBUTION FUNDAMENTALS. By F. E. Sanford. Second edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 252 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$3.50. Presenting essential data for practical application, the volume explains how the distribution system works; how the system is planned, designed and constructed; and how service and operating routine is handled. The two principal changes in this second edition are the addition of the trigonometric method of calculations to the explanation of vector addition, and the inclusion of a new chapter on transformer operation.

INDUSTRIAL EXPERIMENTATION. By K. A. Brownlee. Chemical Publishing Company, Brooklyn, N. Y., 1947. 151 pages, diagrams, charts, tables, 9 by $5^1/_2$ inches, cloth, \$3.75. Of primary interest to those concerned with pilot-plant and plant-scale experiments on chemical manufacturing processes, this volume, British in origin, is a guide to both the planning and interpretation of experiments on an industrial scale and paves the way to efficient quality control. The subject is treated from the practical point of view.

INDUSTRIAL HEALTH ENGINEERING. By A. D. Brandt. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1947. 395 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by $5^3/_4$ inches, cloth, \$6. Beginning with a discussion of industrial atmospheric contaminants and their significance, this volume proceeds to describe the principles of control available and the types of equipment used: collectors, exhaust systems, respirators, and so forth. Design data and other aspects of interest to the practical engineer are included. There is a 12-page bibliography.

MAGNETIC CONTROL OF INDUSTRIAL MOTORS. By G. W. Heumann. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. 589 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$7.50. Of interest to engineers concerned with industrial control equipment, this volume provides exhaustive coverage of electric motor performance, characteristics of control devices, and functions of commonly-used control circuits. Fundamental information is provided as well as information on new devices such as the amplidyne control and a-c hoist controls.

PATENT NOTES FOR ENGINEERS. Published by RCA *Review*, Radio Corporation of America, RCA Laboratories Division, Princeton, N. J., 1947. 165 pages, diagrams, tables, $9^1/_4$ by $5^3/_4$ inches, cloth, \$2.50 plus 20 cents postage if outside of United States. First in a new series of books on subjects of general engineering interest, this volume represents an effort to bridge the gap between engineers, research workers, and inventors generally, and their patent attorneys. Statutory inventions are treated at length. Practical suggestions are offered for protecting inventions prior to the filing of patent applications and thereafter, including the prosecution of patent applications, interference actions, and ownership questions.

LES CATHODES CHAUDES, THÉORIE ET PRATIQUE. By C. Biguenet. Éditions de la Revue d'Optique Théorique et Instrumentale, 165 rue de Sèvres, Paris 15^e, France 1947. 183 pages, illustrations, diagrams, charts, tables, 9 by $5^1/_2$ inches, paper, 300 frs. Devoted to the practical and theoretical study of hot cathodes, this volume includes a discussion of the basic principles of industrial vacuum technique, the use of induction heaters in releasing gas from metals, the study of adsorption phenomena, the theory of electronic emission, and the study of mono-atomic-coated cathodes.

CHEMICAL ENGINEERING FUNDAMENTALS. (Chemical Engineering Series.) By C. G. Kirkbride. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 419 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$5. This book presents the fundamentals of chemical engineering for use in college courses taken prior to those covering the applications of these principles to unit operations and chemical processes. Knowledge of general college chemistry, calculus, and elementary mechanics, sound, and heat are prerequisites. Special attention is devoted to human relations and to the reporting of technical results.

ELECTRONIC CIRCUITS AND TUBES. By the electronics training staff of the Cruft Laboratory, Harvard University. Published by McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 947 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$7.50. This book, together with its companion volume, "Transmission Lines, Antennas and Wave Guides," comprises the lecture material given in a course of instruction in preradar training for officers in the armed forces. The present volume covers the basic theory of electronic tubes and electric circuits employed in conjunction with electronic tubes, with emphasis on the applications in the fields of communication and electronic control.

ELEMENTARY ENGINEERING THERMODYNAMICS. By V. W. Young and G. A. Young. Third edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 268 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$3. As in the previous editions, the purpose is to give the engineering student a sound theoretical foundation for the study of heat and power apparatus. This revision embodies the changes in recent years and places greater stress on the application of thermodynamics to practical design. New material has been added on the Brayton cycle, and a chapter on atmospheric air and the psychrometric chart is included.

ELEMENTS OF ACOUSTICAL ENGINEERING. By H. F. Olson, Second edition. D. Van Nostrand Company, Toronto, Ontario, Canada, New York, N. Y., London, England, 1947. 539 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$7.50. Presenting the principles and applications of acoustics for the engineer and applied scientist, this volume covers the important new instruments, designs, developments, and present-day practices of acoustical engineering. A large number of useful formulas, tables, and graphs are included. Two new chapters on underwater sound and super- and ultrasonics have been added.

ENGINEERING TESTS: CIVIL, MECHANICAL AND ELECTRICAL. (Arco Civil Service Series.) By A. Liebers. Arco Publishing Company, 480 Lexington Avenue, New York 17, N. Y., 1947. 49 pages; civil engineering test questions, sample examinations, 24 pages, diagrams, tables, $10^1/_2$ by 8 inches, paper, \$2.50. This volume presents a careful selection of Civil Service engineering tests with answers, for the use of those who wish to enter public service. The various types of examination questions are demonstrated, acceptable work methods are indicated, and sample examinations with the time limits are included for self-checking.

ESCALATOR METHOD IN ENGINEERING VIBRATION PROBLEMS. By J. Morris, with a foreword by G. Temple. John Wiley and Sons, New York, N. Y., 1947. 270 pages, diagrams, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, \$4.50. The escalator process, devised for the solution of Lagrangian frequency equations, makes it possible to treat a complicated system in a simple manner by dealing with its constituent parts. The solution of each of these parts is made available with appropriate linking co-ordinates or reactions. The complete system is solved in manageable form by the elimination of these linkages, furnishing an effective means for dealing with vibration problems.